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Stratigraphy of the lower part of the Kobiwako Group around the Ueno bosin, Kinki district, Japan

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(with 2 Tables and 24 Figures)

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I Introduction

The Kobiwako Group (NAKAMURA, 1929) is distributed in the Ueno and Omi basins. The group is more than 1,500 m in thickness and consists of fluvio-lacustrine clastic sediments. It is divided into eight formations. These are the Ueno, the Iga, the Ayama, the Koka, the Gamo, the Kusatu, the Katata and the Takashima Formations in ascending order. The sedimentary basin of the Kobiwako Group originated around the Ueno basin in early Pleistocene times, about four million years ago (TAKAYA, 1963; KONDO, 1968), and subsequently migrated to present-day Lake Biwa (YOKOYAMA, 1969). However, the manner in which the basin was born and how the migration occurred could not be established in detail, since the detailed stratigraphy of the lower part of the group remained to be determined.

In a detailed geologic survey under taken by the present author, the stratigraphy and geological structure of the lower part of the Kobiwako Group around the Ueno basin were recently clarified, and the sedimentary facies and thickness of the strata were analyzed. On the basis of the field data obtained, the sedimentary environments and tectonic movements in the Pliocene Kobiwako sedimentary basin were elucidated. The results of this study, especially concerning the stratigraphy of the group, are presented in this report.

II General geology

The Kobiwako Group crops out around the Shimagahara, the Hananoki, the Southeastern hills of Ueno City, the Iga, the Oyamada, the Ayama and the Koka. These areas are separated from each other by rivers and their alluvial plains or the distribution of basement rocks.

The lower part of the Kobiwako Group in the Ueno and the southeastern part of the Omi basins overlies the granitic and metamorphic rocks of the Ryoke Complex. The group generally dips to the north, so that its lower to upper strata crop out from south to north. The group measures about 800 m in total thickness, and can be lithologically

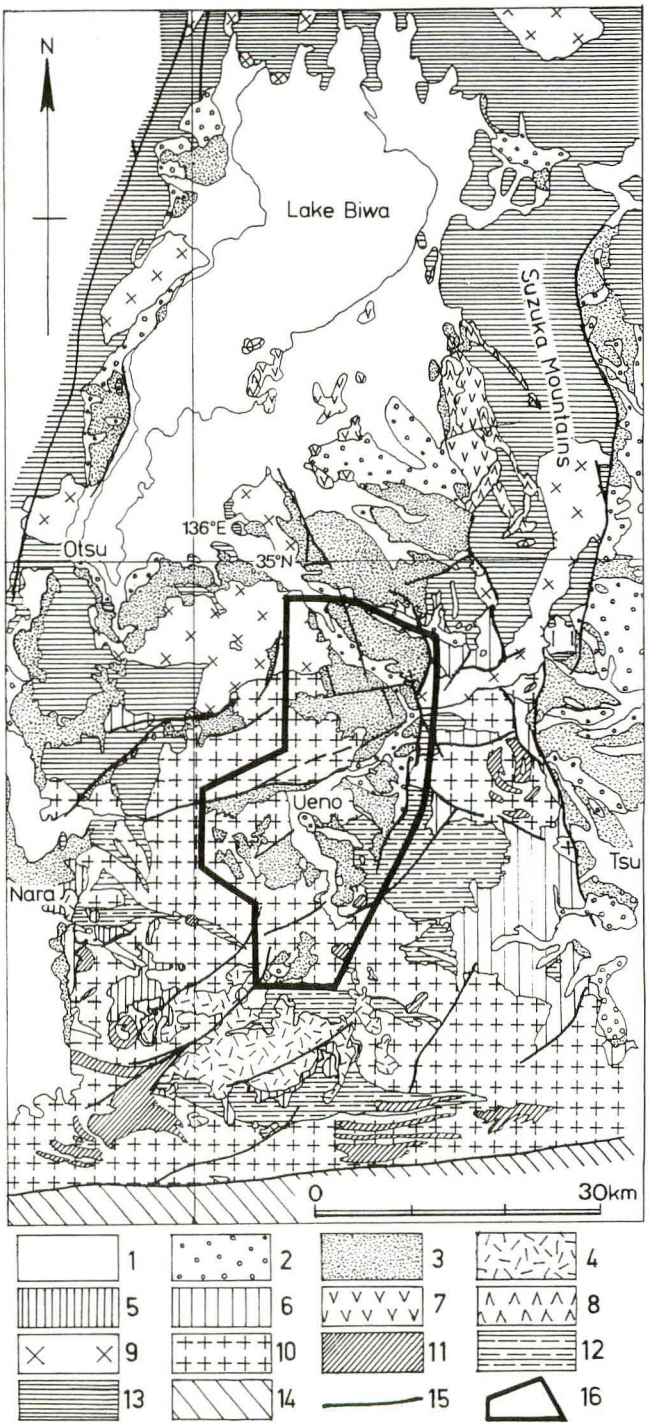

N
Lake Biwa
Suzuka Mountains
136°E
35°N
Otsu
Ueno
Tsu
Nara
0
30km
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

Fig. 1

divided into five formations. These are the Ueno, the Iga, the Ayama, the Koka and the Gamo Formations in ascending order.

The Ueno Formation, of 300 m in maximum thickness, consists chiefly of fluvial and marsh sand, silt and clay. The Iga Formation, of 180 m in maximum thickness, is made up largely of fan and fluvial gravels and sand beds. The Ayama Formation, of 100 m in maximum thickness, is composed chiefly of lacustrine clay with intercalating deltaic sand and local fan gravels. The Koka Formation, of 120 m in maximum thickness, consists mainly of lacustrine clay with intercalating deltaic sand. The lower part of the Gamo Formation, of more than 190 m in maximum thickness, is made up chiefly of deltaic and fluvial alternations of sand and silt.

The group in the Ueno and the southern part of the Omi basins is divided into more than nine rectangular fault-blocks by three sets of faults treding northeast-north, north-northwest and east-northeast, respectively. The thickness of the group is extremely variable between each fault-block. For example, the Ueno Formation measures 150 m in the Ueno block, 40 m in the Shimagahara block, more than 230 m in the Iga and the Oyamada blocks, 20 m in the Ayama block, and more than 40 m in the Koka block.

III Stratigraphy of the Kobiwako Group

The Kobiwako Group is extremely varied in its lithofacies and thickness in each fault-block or area mentioned above. For this reason, the detailed stratigraphy of the group will be described according to area.

A. Ueno Formation

The Ueno Formation comprises the lowermost part of the Kobiwako Group, and overlies the basement Ryoke Complex. This formation is distributed mainly in the southern part of the Ueno basin, i.e. in the Shimagahara area, the Hananoki area, the Southeastern hills of Ueno City and the Oyamada areas. The formation, of 250 m in maximum thickness, is composed mainly of clay in the Oyamada area, while it consists chiefly of alternations of silt, sand and gravel in the Hananoki area and the Ayama area.

The Ueno Formation is subdivided into two submembers which are designated as the Lower Yono and the Upper Yono Submembers in the Hananoki area, and into two members which are designated as the Hojiro and the Nakamura Members in the Iga and Oyamada areas. In the Southeastern hills of Ueno City, the formation is subdivided

Fig. 1 Geologic sketch map around the Ueno and the Omi Basin. 1: Holocene deposits, 2: terrace deposits, 3: Plio-Pleistocene Series (the Osaka, the Kobiwako and the Agé Group), 4–5: Miocene Muro Volcanic Rocks (4: acidic tuff, 5: sedimentary rocks), 6: Lower Miocene Series (the Yamagasu, the Yamabe, the Tuzuki, the Fujiwara, the Ichishi and the Suzuka Groups), 7–9: Upper Cretaceous volcanics (7: welded tuff of the Koto Rhyolitic Rocks, 8: Dyke rocks of the Koto Rhyolitic rocks, 9: granite), 10–12: Ryoke Complex (10: granite, 11: metamorphic rocks, 12: ultramafic rocks), 13: Paleo-Mesozoic Tamba Belt, 14: Sambagawa Metamorphic Rocks, 15: Fault, 16: the study area

into three members. These are the Ryoshudani, the Ichibe and the Tomono Members in ascending order.

1. Hananoki area

In the Hananoki area, the Ueno Formation is 200 m in thickness, and consists mostly of clay, sand and gravel. The formation is mainly conformably overlain by the Iga Formation, and locally unconformably in the western part of the Hananoki area. In this area, the Ueno Formation is lithologically divided into two submembers, i.e. the Lower Yono and the Upper Yono Submembers in ascending order. The boundary between the two submembers is exactly above the Nishide Volcanic Ash Layer.

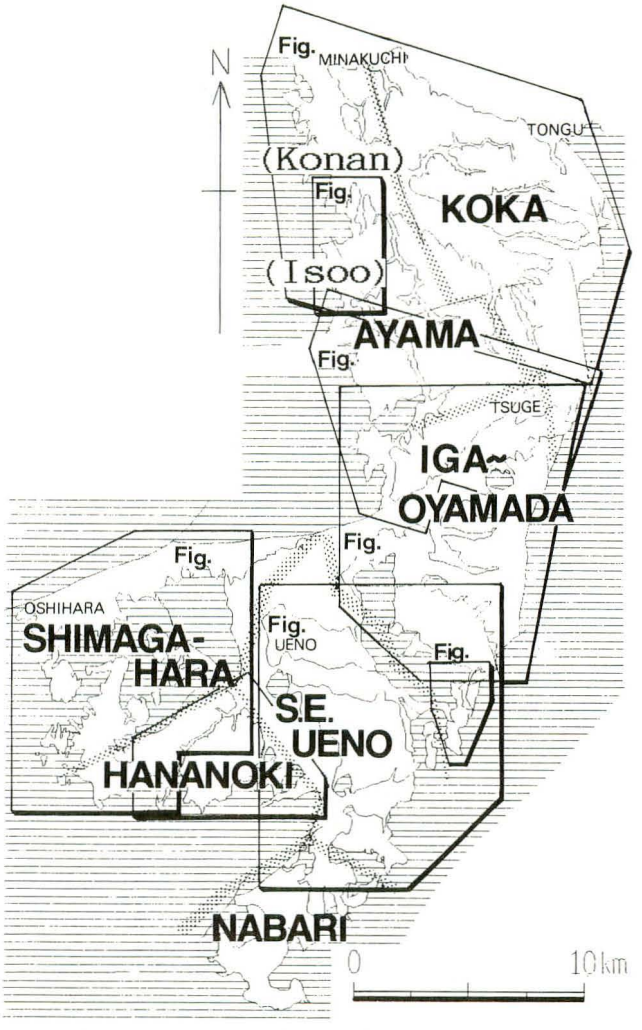


Fig. 4 Index map of each of local geologic map.

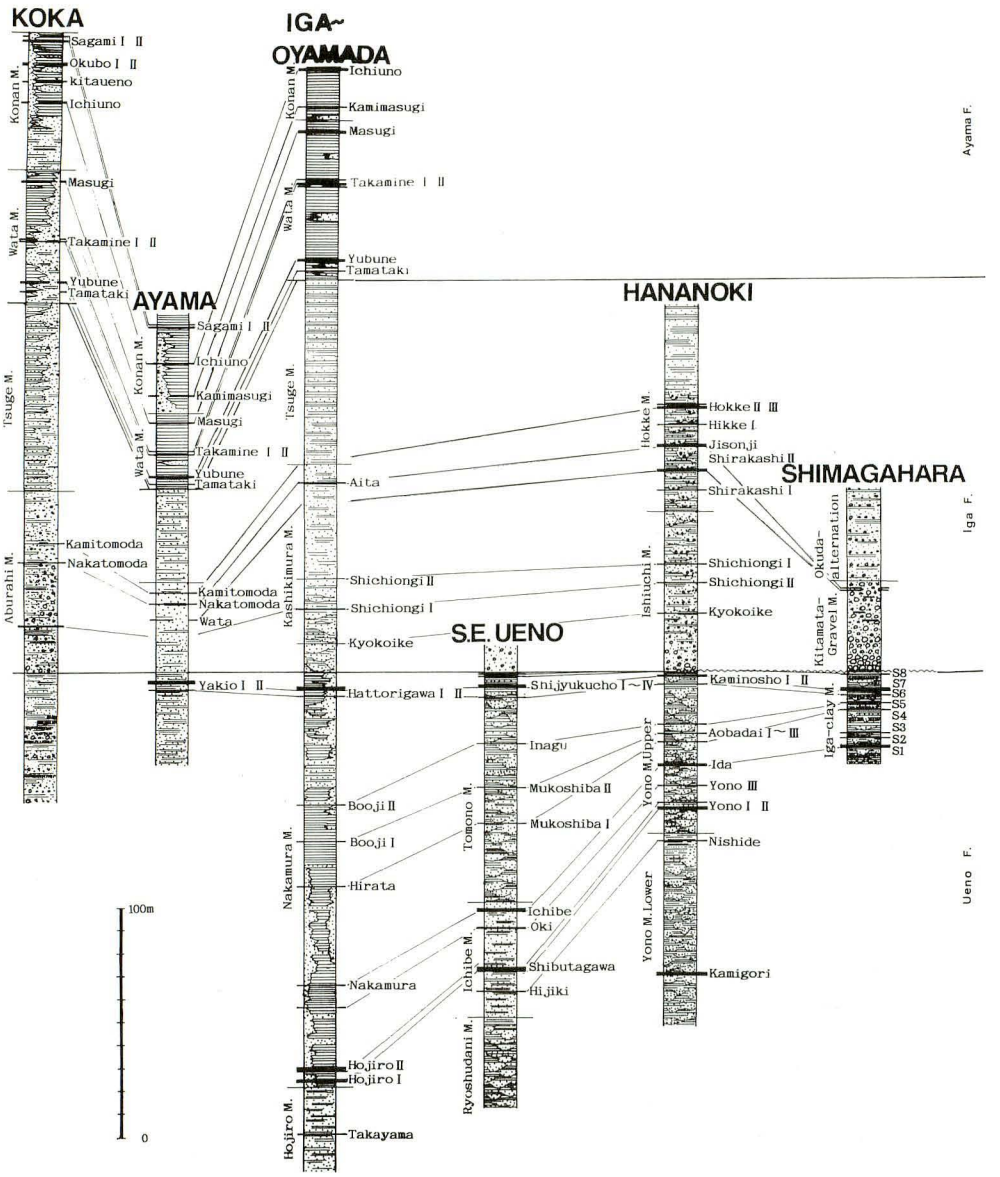


Fig. 5 Standard columnar sections of the Kobiwako Group around the Ueno Basin, and their correlation.

a. Lower Yono Submember

The Lower Yono Submember, of 70 m in maximum thickness, is made up chiefly of lenticular pebbly sand and poorly-sorted clay beds with sheets of sand. The basal layers of the submember contain granitic fragments. This submember reveals the largest exposure in the south of the Hananoki area. The type locality is situated along the road

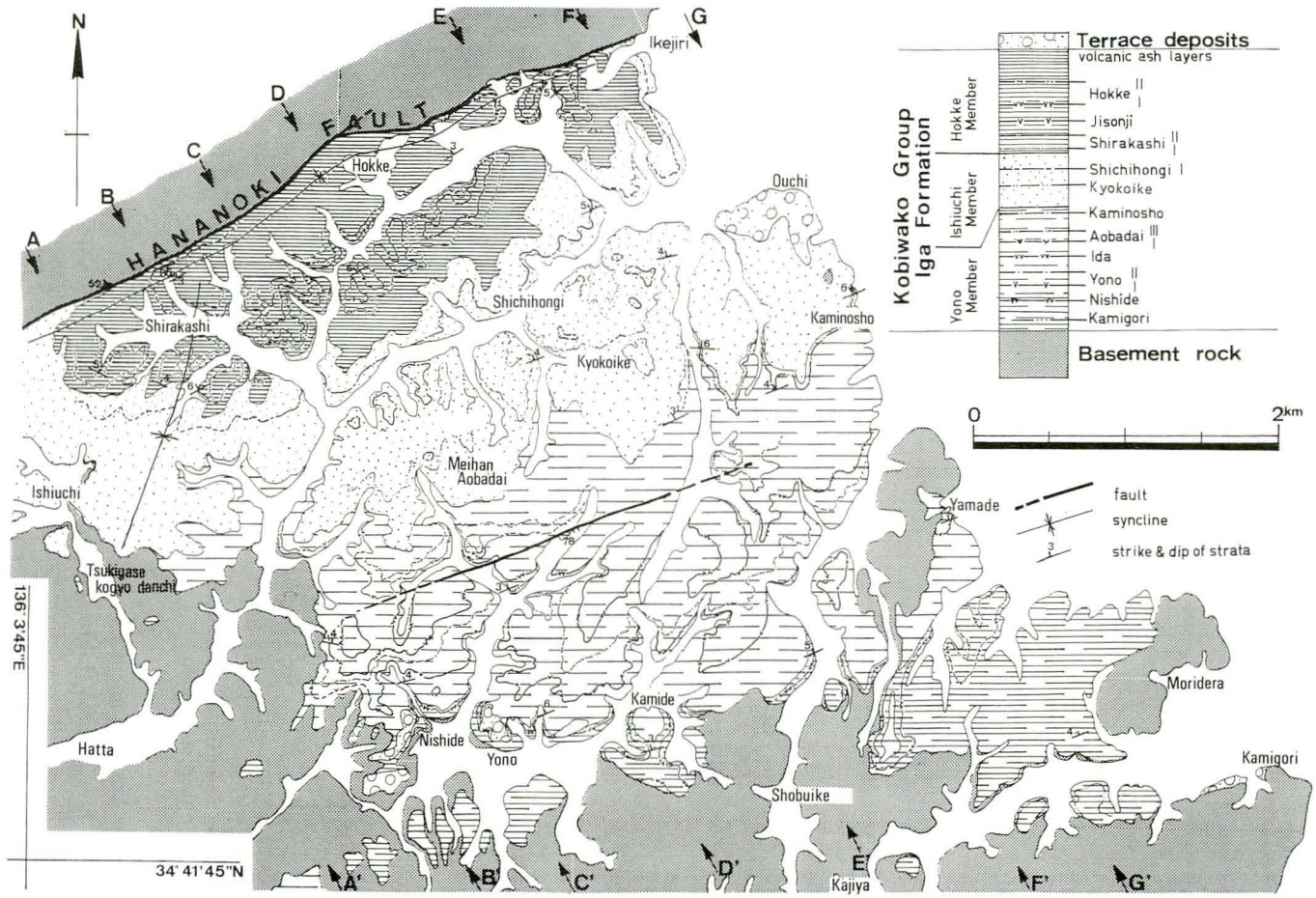


Fig. 6 Geological map of the Hananoki area.

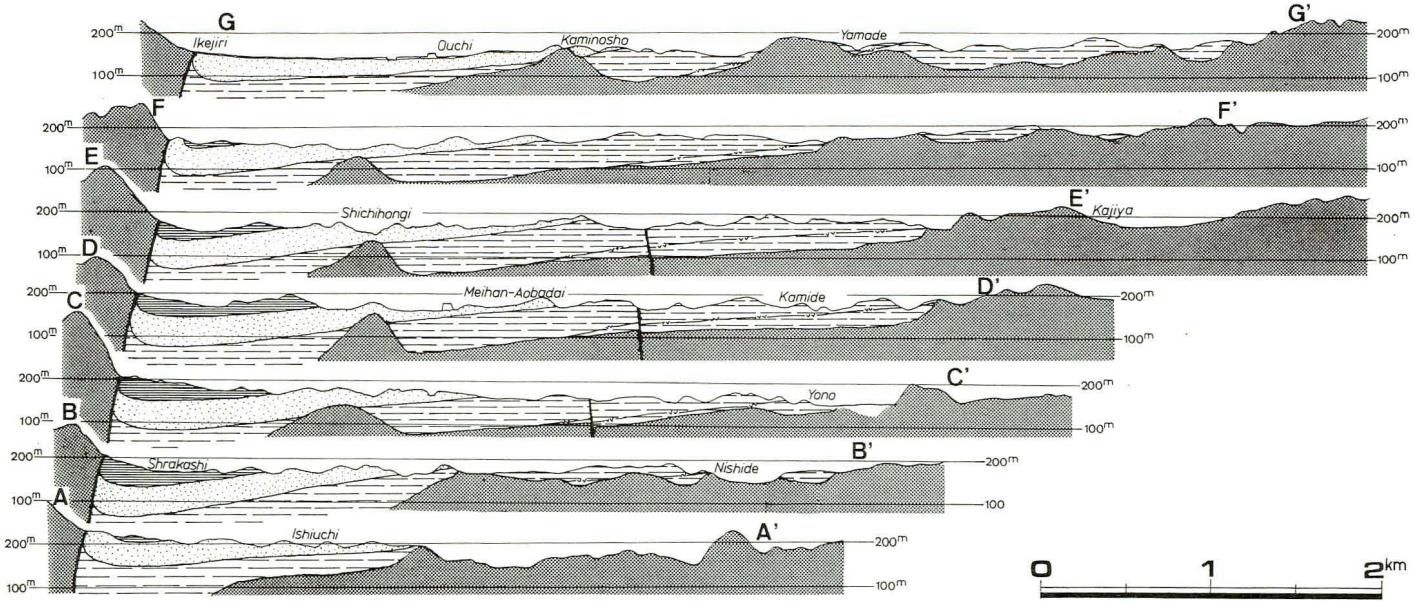


Fig. 7 Geological cross sections of the Hananoki area.

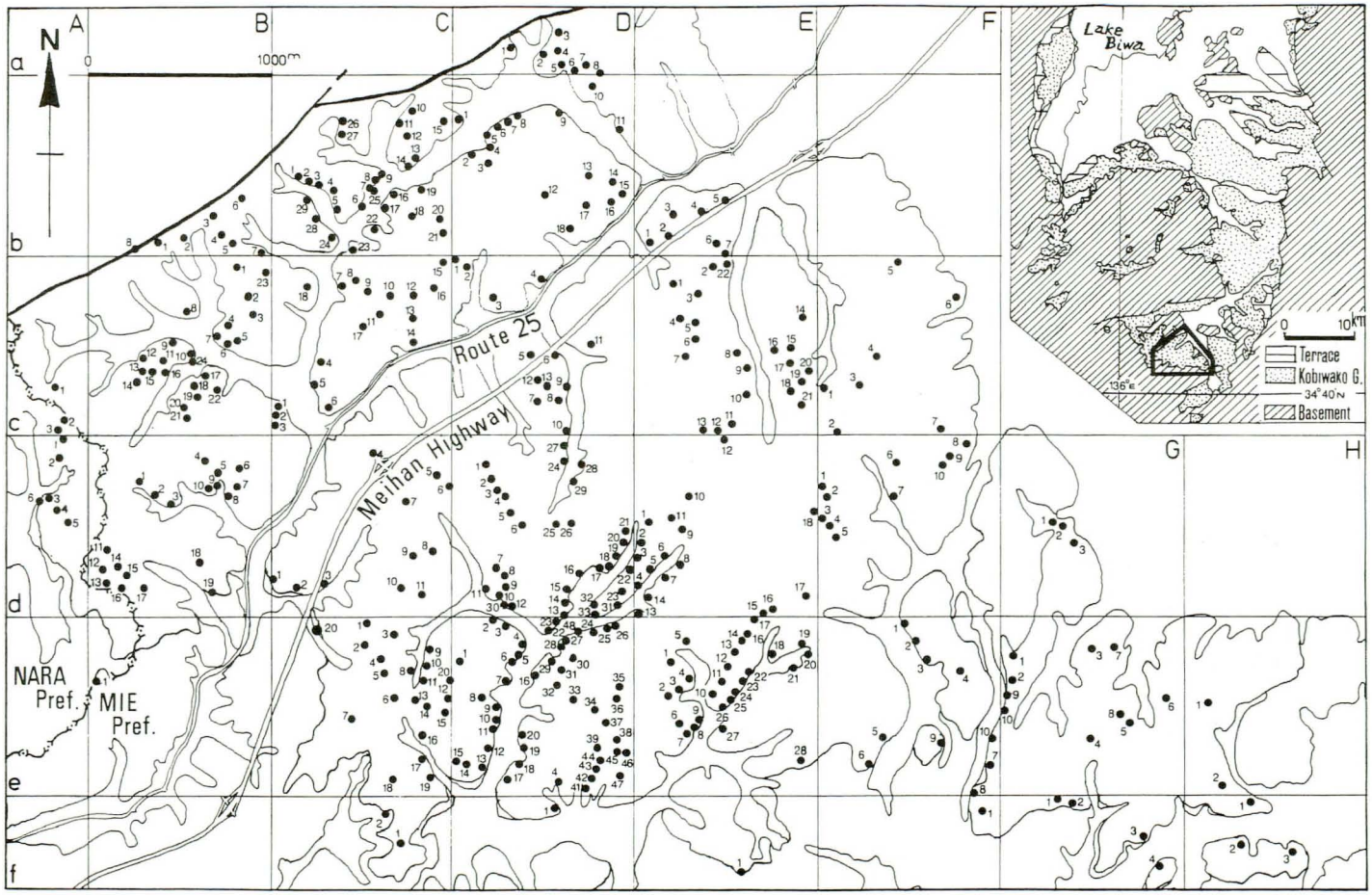


Fig. 8 Index map of each columnar section (Fig. 9) in the Hananoki area.

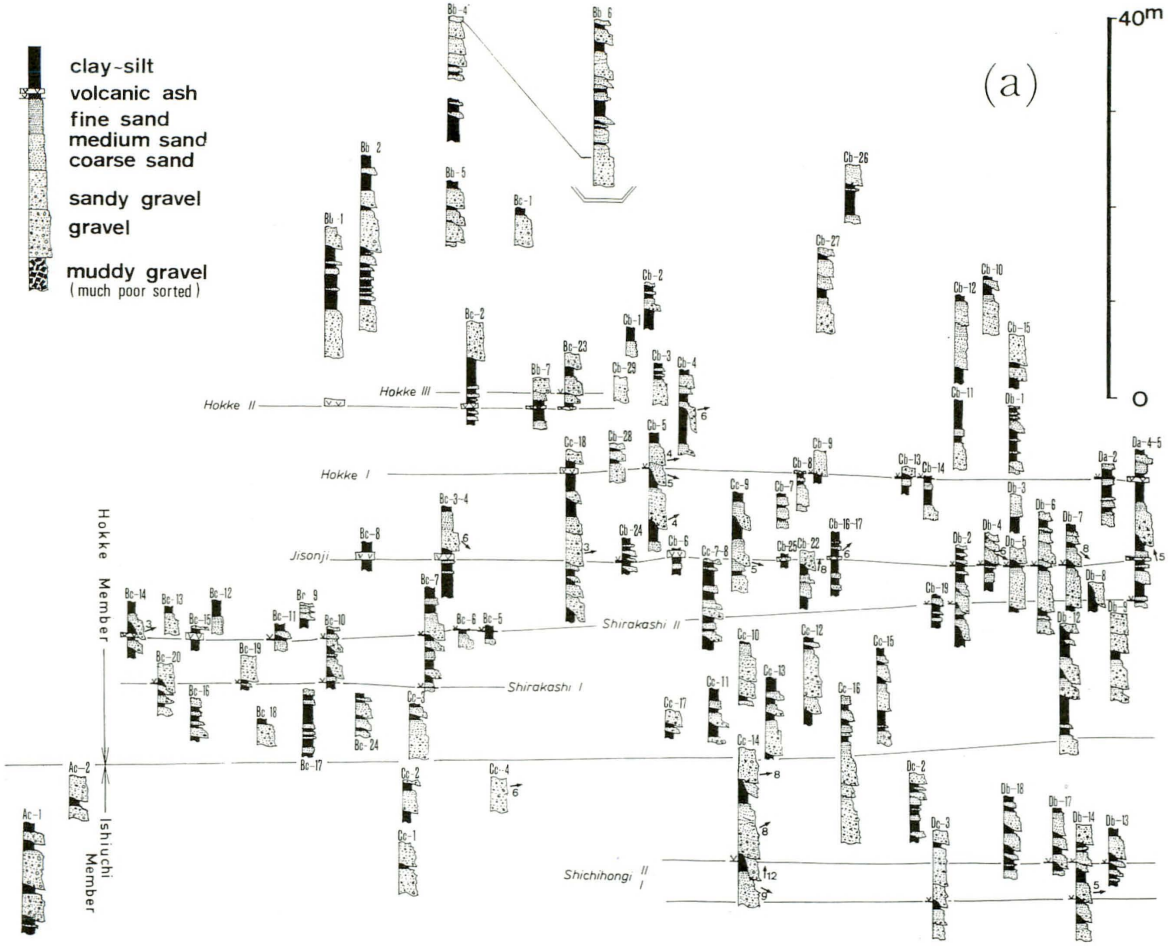

clay-silt
volcanic ash
fine sand
medium sand
coarse sand
sandy gravel
gravel
muddy gravel
(much poor sorted)
(a)
40m
0
Hokke II
Hokke III
Hokke I
Jisonji
Shirakashi II
Shirakashi I
Shichihongi II
Shichihongi I
Hokke Member
Ishiuchi Member

Fig. 9(a)


(b)
40m
0
Ishiuchi Member
Yono Member
Shichirangi I
Kyokoike
Kaminasho II
Kaminasho I
Aobadai III
Aobadai II
Ida

Fig. 9(b)

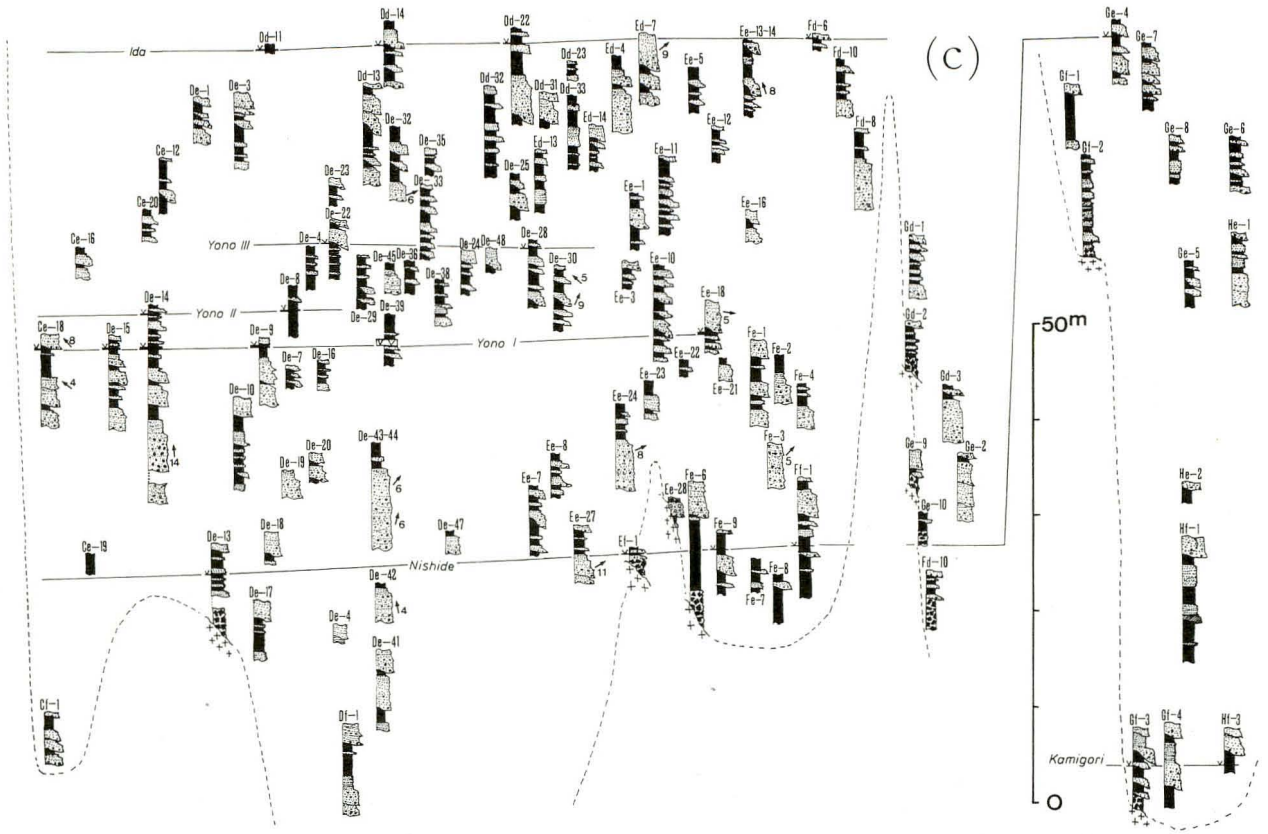


Fig. 9(c)

Fig. 9 Columnar sections of the Kobiwako Group in the Hananoki area. Locality of each columnar section is shown in Fig. 8. Allows on right side of the columnar sections show the directions of paleocurrent, and numbers are of mesurments.

from Moridera to Kajiya in Ueno City.

The poorly-sorted clay beds range from 0.5 to 2 m in thickness. They are vegetationally biotervated and usually contain root remains of plants. The pebbly sand beds, ranging from 0.1 to 1.5 m in thickness, are massive with a muddy matrix, and contain subangular to subrounded granitic pebbles.

Within this submember, more than two volcanic ash layers are intercalated. They comprise the Kamigori and Nishide Volcanic Ash Layers in ascending order.

b. Upper Yono Submember

The Upper Yono Submember, of 90 m in maximum thickness, is composed of lenticular sandy gravel and sorted clay beds with sheets of sand. The lithological facies of this submember is generally coarser and better sorted than that of the Lower Yono Submember. This submember crops out mainly in the middle of the Hananoki area. The type locality is situated along the road from Yono to Meihan-Aobadai in Ueno City.

The lenticular sandy gravel beds are usually about 1.5 m in thickness and exhibit cross-bedding. The base of each lenticular sandy gravel bed mostly has a concave erosional surface. The beds have a sandy matrix, and are composed chiefly of fragments of chert and sandstone from the Tamba Belt, granite, gneiss and aplite from the Ryoke Complex, and welded tuff of the Muro Volcanic Rocks with minor amounts of rhyolitic tuff from the Koto Rhyolitic Rocks. In the clay beds, vegetational biotervation is usually present. The sheets of sand are composed of medium- to fine-grained sand. They display parallel lamination when they overlie the clay beds without an erosional surface, and when they overlie them with a slight erosional surface, trough- or planar- type cross laminations are usually recognized.

Within the Lower Yono Submember, nine volcanic ash layers are intercalated. They comprise the Yono I, Yono II, Yono III, Ida, Aobadai I, Aobadai II, Aobadai III, Kaminosho I and Kaminosho II Volcanic Ash Layers in ascending order.

2. Shimagahara area

In this area, the Ueno Formation is known as the Iga Clay Member (KONDO, 1968). The formation is unconformably overlain by the Iga Fomration in the area.

a. The Iga Clay Member (KONDO, 1968)

This member, of 40 m in maximum thickness, consists chiefly of arkose muddy sand beds, porcelain clay beds called the "Gaerome clay" and the "Kibushi clay," lenticular sorted sand beds, sheets of silt and lignite beds. The arkose muddy sand beds, ranging from 0.5 to 2 m in thickness, are massive with a muddy matrix and granitic angular to subangular pebbles. The lenticular sand beds range from 0.2 to 2 m in thickness and 0.5 to 5 m in width. The base of each sand bed is concave, and top is convex. In most parts of these sand beds, tabular- or trough-type cross-lamination is observed. The sheets of silt generally exhibit current ripples and/or parallel lamination. The "Gaerome clay," ranging from 0.5 to 4 m in thickness, appears to be of the same facies as the arkose muddy sand beds, but includes abudant clayey matrix. Thses deposits grade laterally into each other.

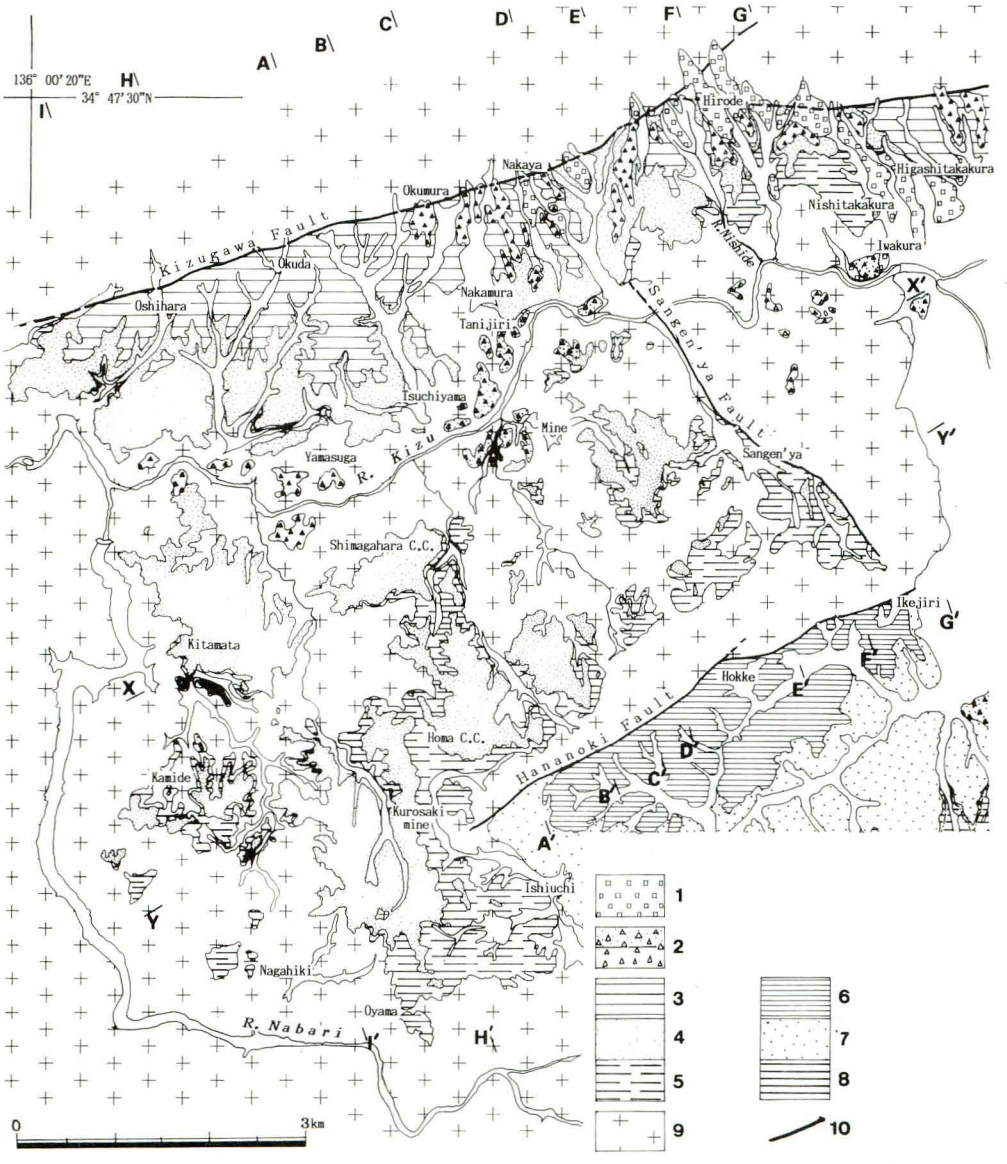


Fig. 10 Geological map of the Shimagahara area. 1: lower terrace deposits, 2: middle terrace deposits, 3–5: the Kobiwako Group in Shimagahara area (3: the Okuda Member, 4: the Kitamata Member, 5: the Iga Clay Member), 6–8: the Kobiwako Group in Hananoki area (6: the Hokke Member, 7: the Ishiuchi Member, 8: the Upper Yono Subember), 9: granitic rocks, 10: fault.

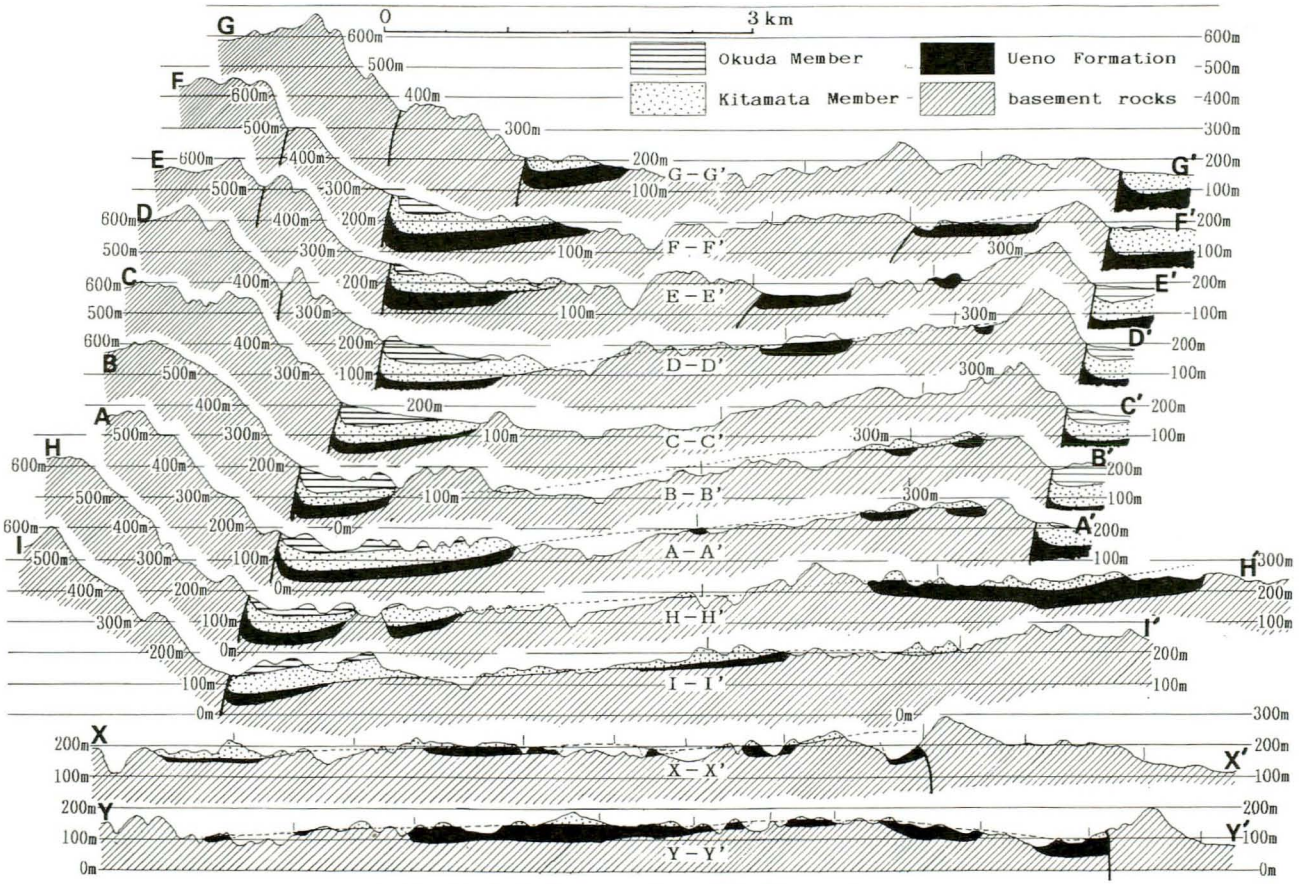


Fig. 11 Geological cross sections of the Shimagahara area.

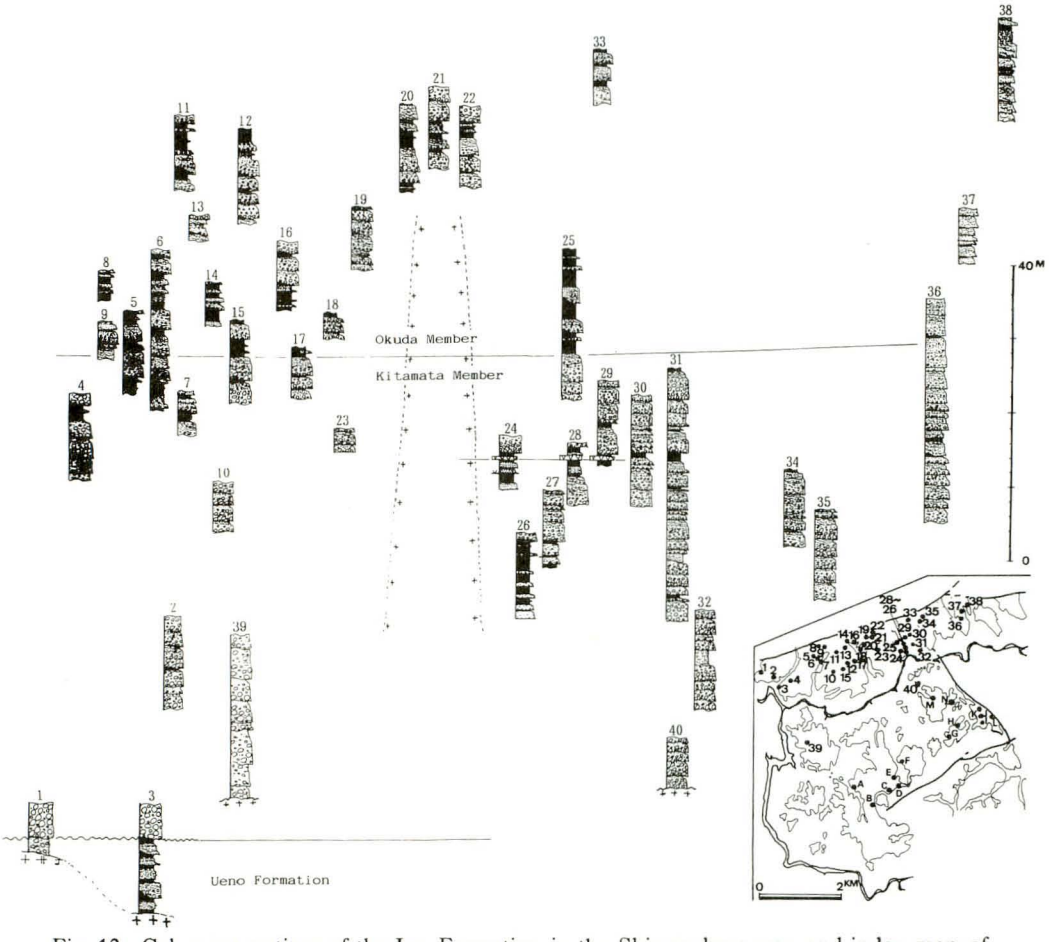


Fig. 12 Columnar sections of the Iga Formation in the Shimagahara area, and index map of each columnar section in the Shimagahara area.

In the northeast of the Hananoki area, this member consists of arkosic coarse sand beds with seams of silt and pebbles of granitic rocks and hornfels.

3. Nabari area

In the Nabari area, the Ueno Formation is more than 100 m in thickness. The lower part of the formation consists mostly of arkosic sand, silt and clay. The silt and clay beds are usually massive and vegetationally biotervated. In the southaest of this area, the lower part of the fromation is composed of subangular to subrounded pebbles of granite, Ryoke metamorphic Rocks and Muro Volcanic Rocks. Within this part of the formation, more than two volcanic ash layers are intercalated. The lowest one is the Kamigori Volcanic Ash Layer. Upper part of the Ueno Formation consists chiefly of arkose sand, silt and clay beds. The Ichibe Volcanic Ash Layer is intercalated in this part of the formation.

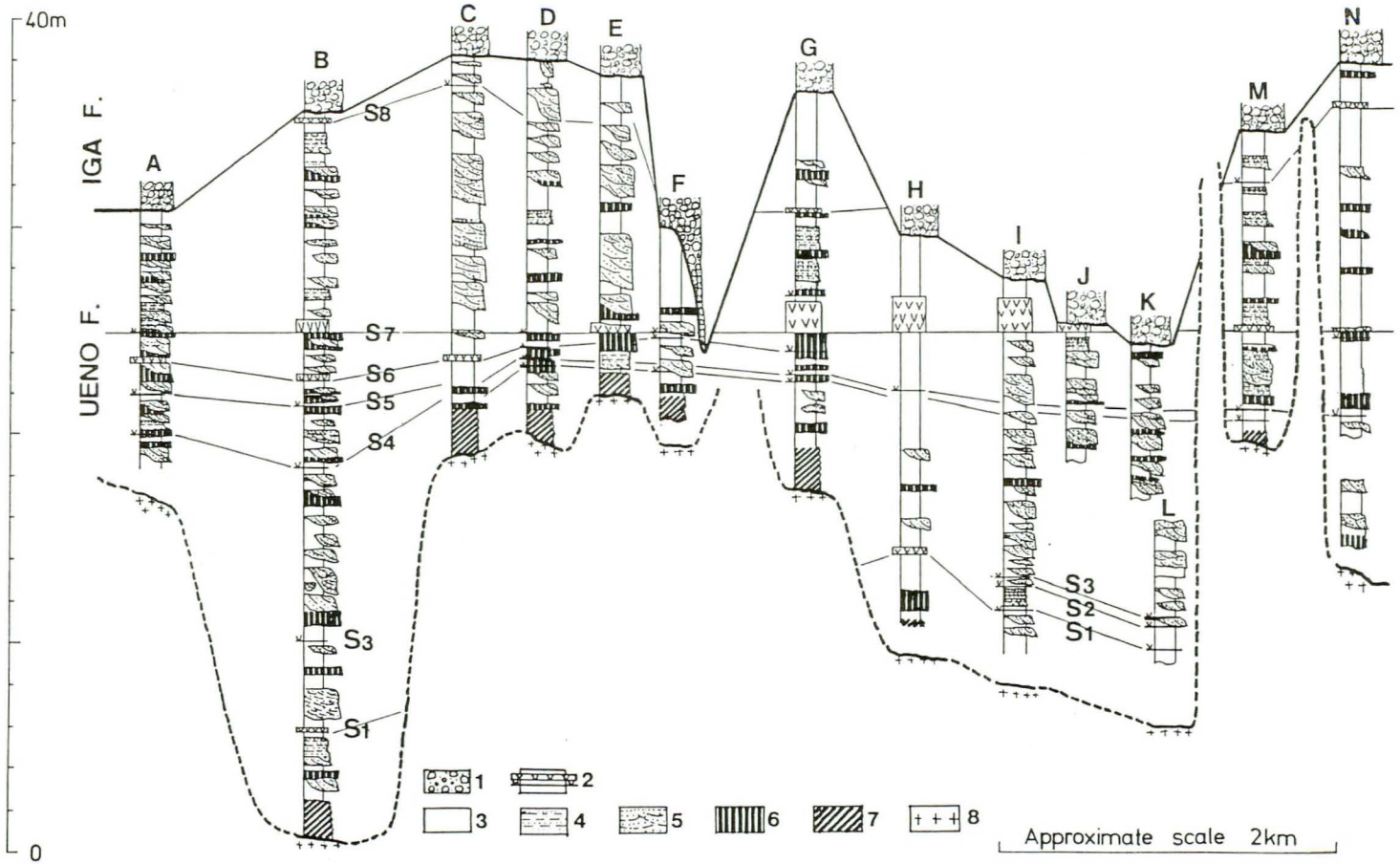


Fig. 13 Columnar sections of the Ueno Formation in the Shimagahara area. Locality of each columnar section is shown in Fig. 12. 1: gravel (of the Iga Formation), 2: volcanic ash layer, 3: clay, 4: silt to very fine sand, 5: arkose coarse sand, 6: lignite, 7: "Gaerome clay," 8: basement granite.

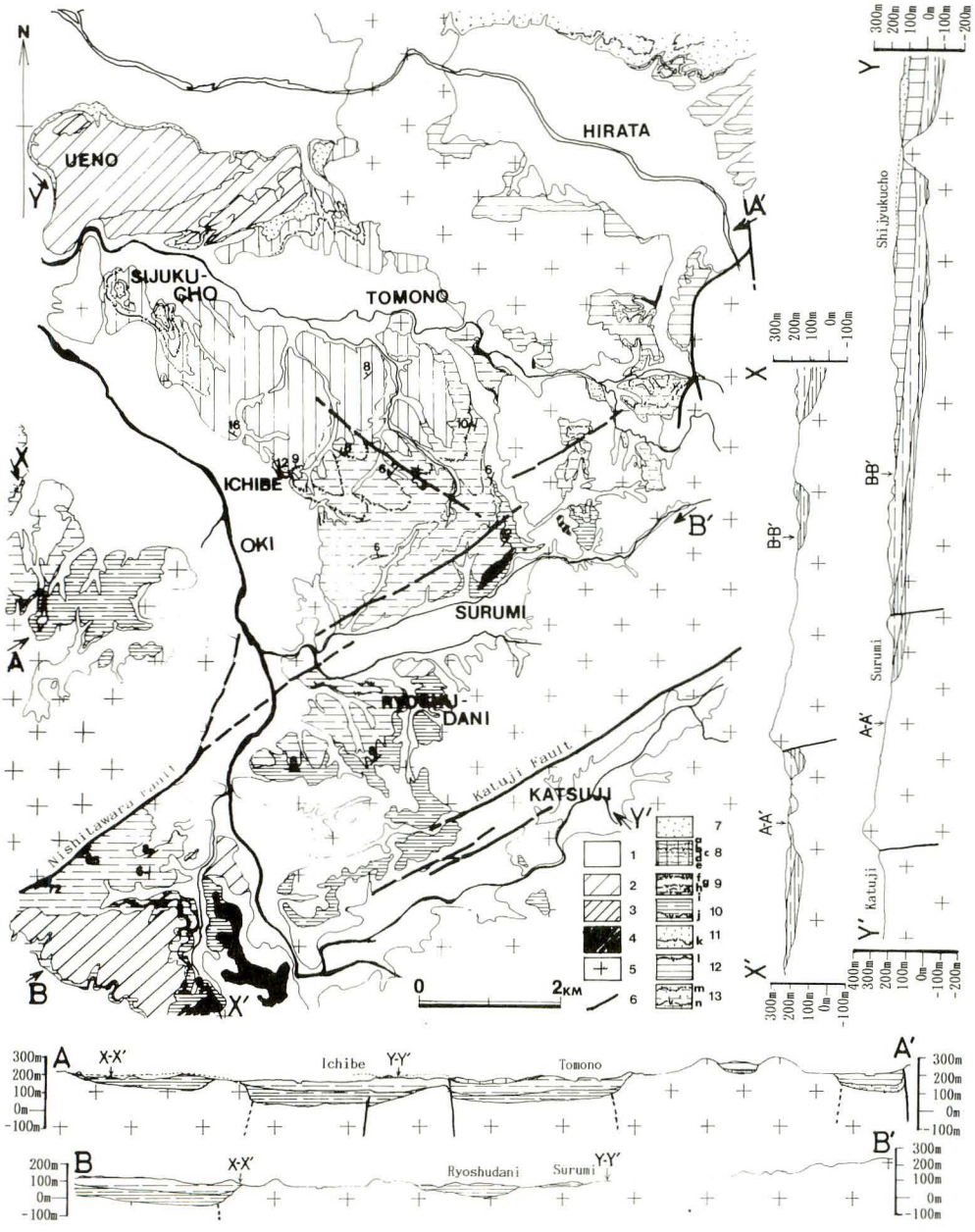


Fig. 14 Geologic map and geologic cross sections of the Southeastern hills of Ueno City. 1: Holocene deposits, 2: lower terrace deposits, 3: middle terrace deposits, 4: higher terrace deposits, 5: basement rocks, 6: fault, 7–10: the Kobiwako group in the Southeastern hills of Ueno City (7: the Iga Formation, 8: the Tomono Member, 9: the Ichibe Member, 10: the Ryoshudani Member), 11–13: the Kobiwako Group in the Iga and the Oyamada areas (11: the Kashikimura Member, 12: the Nakamura Member, 13: the Hojiro Member), a-n: volcanic ash layers in the Kobiwako Group (a: Shijukucho IV, b: Shijukucho II, c: Shijukucho I, d: Inagu, e: Mukoshiba II, f: Ichibe, g: Oki, h: Shibutagawa, i: Hijiki, j: Ryoshudani, k: Shichihongi I, l: Hattorigawa II, m: Hojiro II, n: Hirata Volcanic Ash Layers.

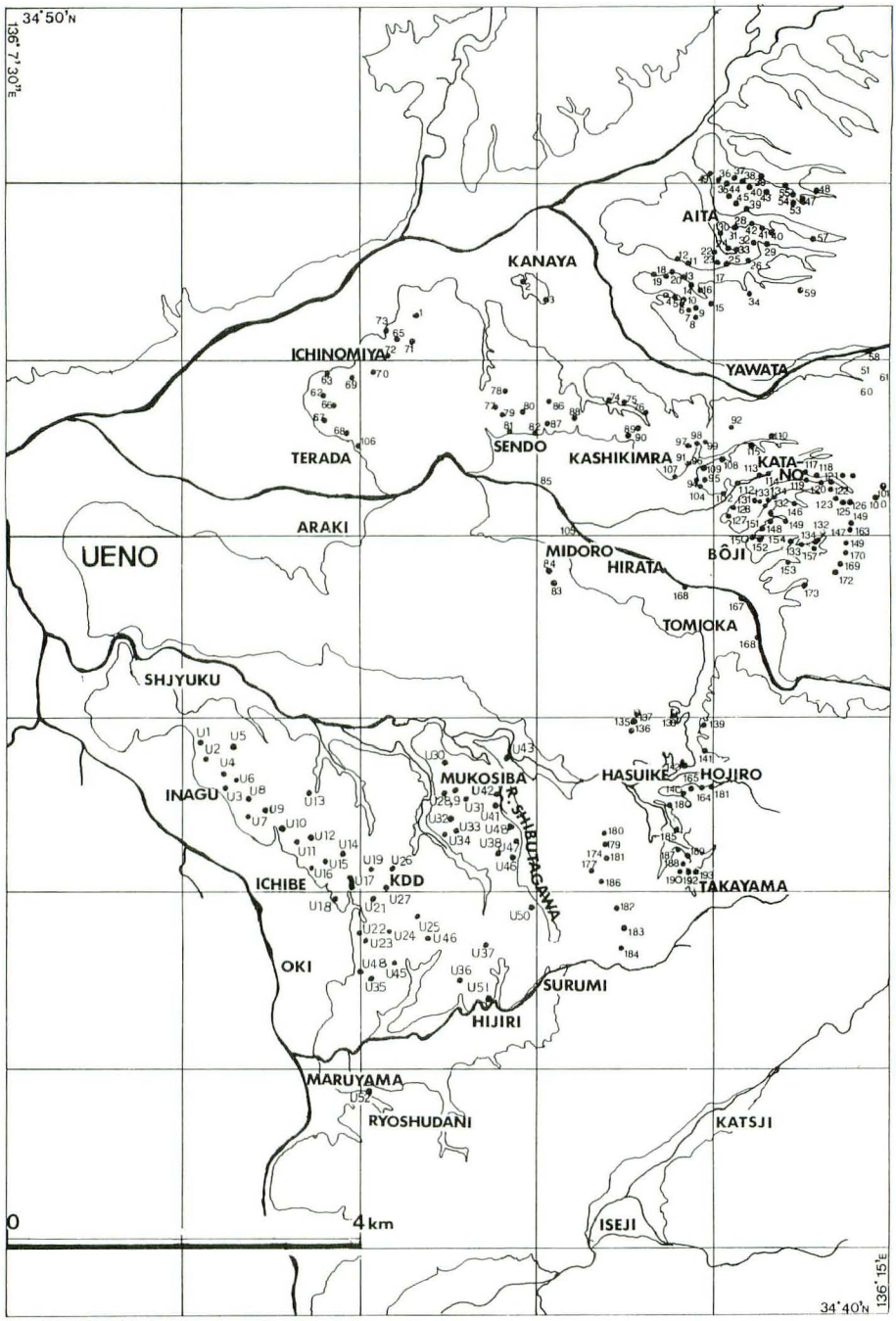


Fig. 15 Index map of each columnar section in the Southeastern hills of Ueno City, the Iga and the Oyamada areas.

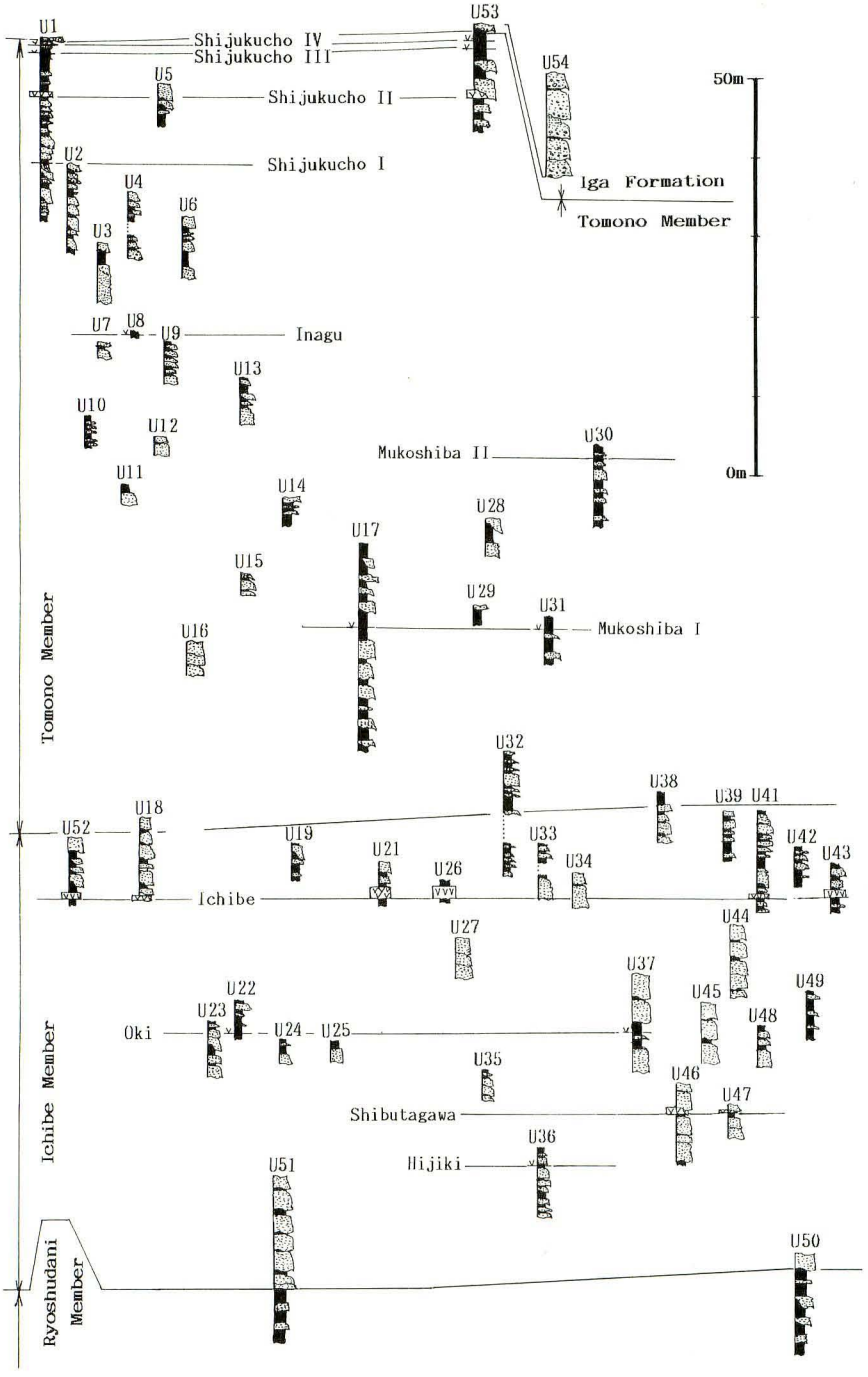


Fig. 16 Columnar sections in the Southeastern hills of Ueno City. Locality of each columnar section is shown in Fig. 15.

4. Southeastern hills of Ueno City

In this area, the Ueno Formation, of about 250 m in thickness, consists of arkosic sand, silt and clay with gravels of granite, Ryoke Metamorphic Rocks and Muro Volcanic Rocks. The formation is subdivided into three members. These are the Ryoshudani, the Ichibe and the Tomono Members in ascending order.

a. Ryoshudani Member

The Ryoshudani Member overlies the basement Ryoke Complex unconformably and is conformably overlain by the Ichibe Member. The Ryoshudani Member crops out mainly in the southern hills of the River Hijiki and around Surumi in Ueno City. This member, of about 50 m in thickness, consists mostly of poorly-sorted silt and clay beds with lenses of arkosic sand and gravels. These lenses of arkosic sand and gravels range from 1 to 2 m in thickness and the base of each bed is asymmetrically concave. The beds mostly show inner structures of epsilon-type cross-stratification.

b. Ichibe Member

This member, of 50 m in thickness, is composed mainly of arkosic pebbly sand, well-sorted middle to fine sand and clay beds. It is widely distributed in the area and conformably overlies the Ryoshudani Member. The type locality is situated in the eastern margin of the area between Ichibe and Inagu.

The arkosic pebbly sand beds range from 1 to 2 m in thickness and extend widely, about 100 m laterally. The base of each bed has irregularly eroded the underlying beds. Parallel lamination and small current ripples occur commonly in the well-sorted middle to fine sand beds, which range in thickness from 20 to 50 cm. The silt or clay beds, ranging from 0.2 to 1 m in thickness, are massive or weakly laminated. In both fine-grained beds, vegetational biotervation and fossil roots of plants are usually present.

Within the Ichibe Member, more than four volcanic ash layers are intercalated. They comprise the Hijiki, Shibutagawa, Oki and Ichibe Volcanic Ash Layers in ascending order.

c. Tomono Member

The Tomono Member, of 100 m in thickness, consists of clay beds and sheets of fine to medium sand aith lenticular arkose sand beds. This member is widely distributed in the northaestern part of this area. The type locality is situated in the northern margin of the area from Kamitomono to Shijuku-cho in Ueno City.

The clay beds are widely distributed, extending more than 150 m laterally, and are rather well sorted. They range in thickness from 0.5 to 2 m. The sheets of fine to medium sand range from 0.2 to 1 m in thickness and have horizontal or current-ripple laminae. The lenticular arkose sand beds range from 1 to 3 m in thickness and the base of each bed is concave. They measure from 10 to 20 m in width.

Within the Tomono Member, more than seven volcanic ash layers are intercalated. They comprise the Mukoshiba I, Mukoshiba II, Inagu, Shijukucho I, Shijukucho II, Shijukucho III and Shijukucho IV Volcanic Ash Layers in ascending order.

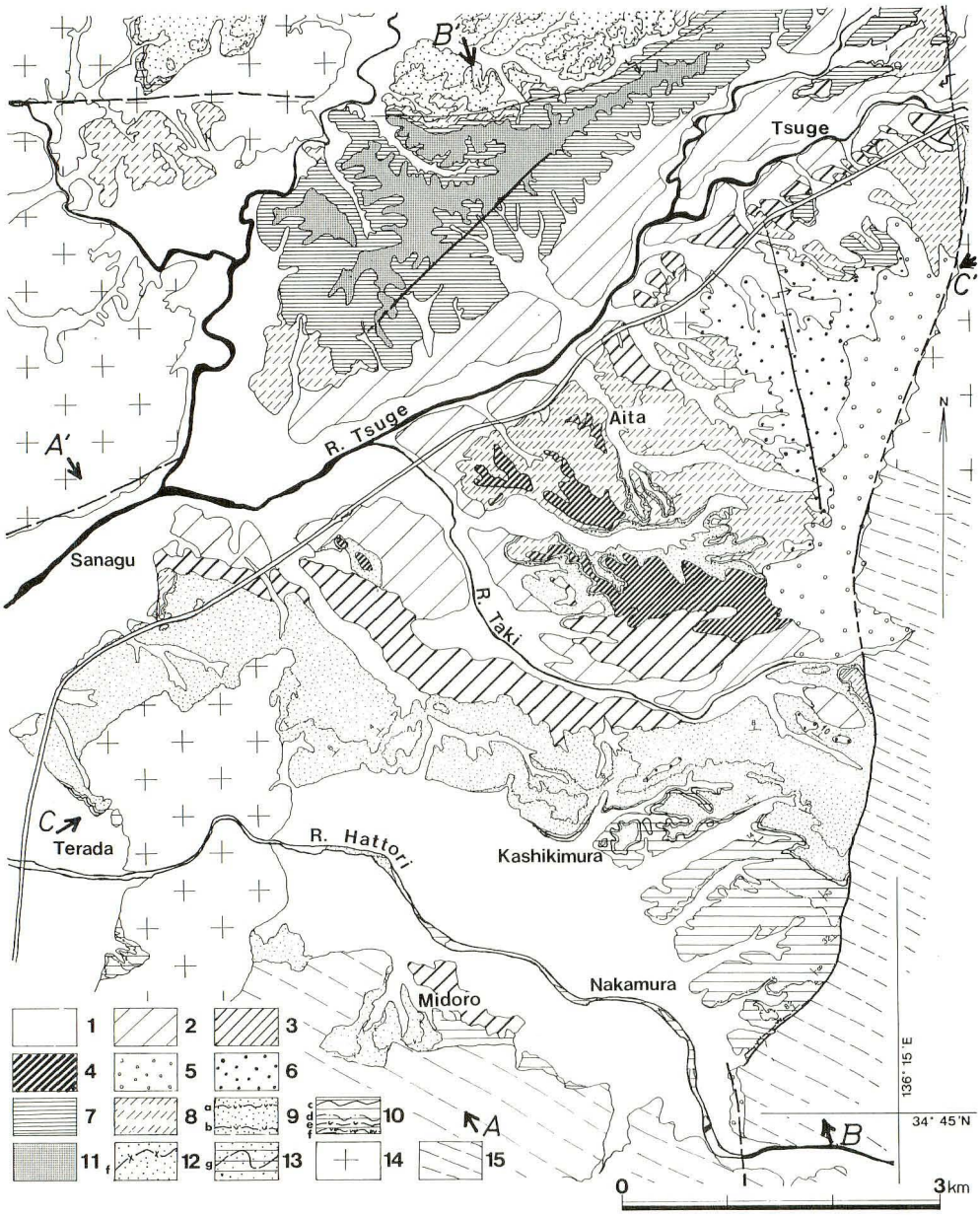


Fig. 17 Geological map of the Oyamada and the southern part of the Iga areas, 1: Holocene deposits, 2: lower terrace deposits, 3: middle terrace deposits, 4: higher terrace deposits, 5: newer talus deposits, 6: older talus deposits, 7–11: the Kobiwako Group in the Iga and the Oyamada areas (7: the Konan Member, 8: the Wada Member, 9: the Tsuge Member, 10: the Kashikimura Member, 11: the Nakamura Member), 12–13: the Kobiwako Group in tbe Ayama Area (12: the Aburahi Member, 13: the Ueno Formation), 14: granite, 15: Ryoke Metamorphic Rocks, a-h: volcanic ash layers in the Kobiwako Group (a: Aita, b: Shichihongi I, c: Hattorigawa II, d: Boji II, e: Nakamura, f: Hojiro II, g: Nakatomoda, and Yakio II Volcanic Ash Layers).

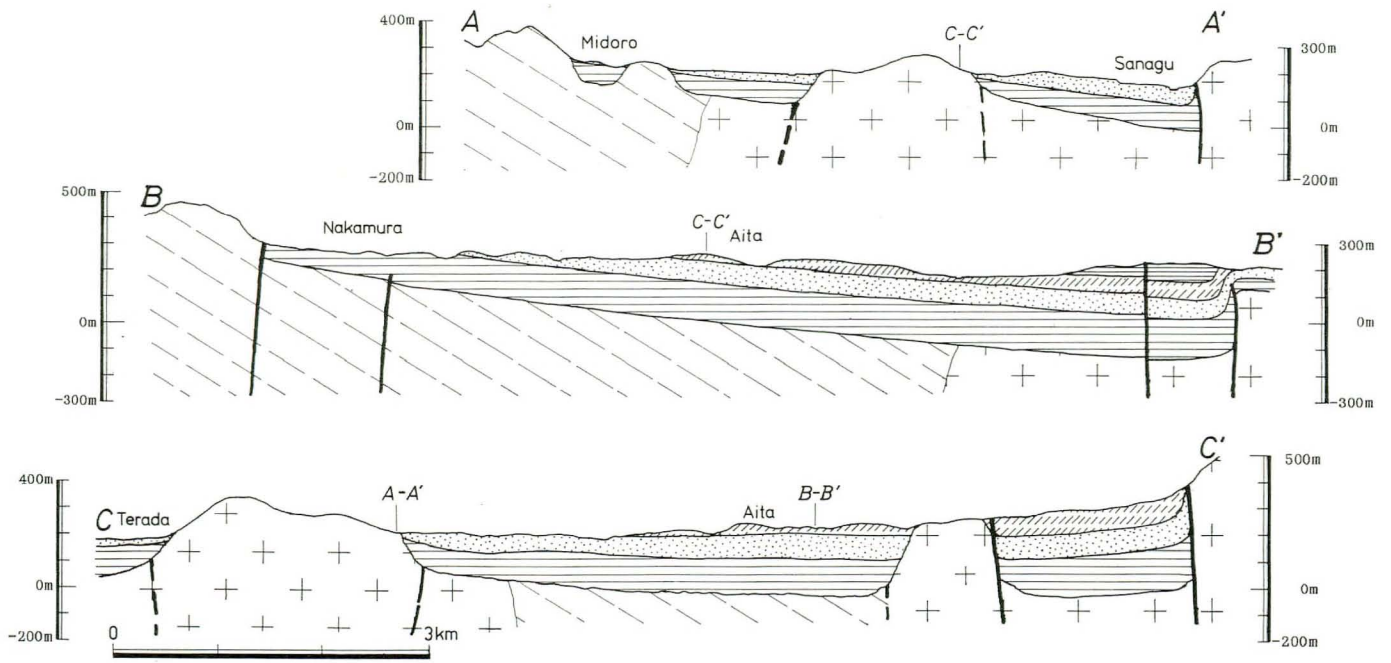


Fig. 18 Geolog al cross sections of the Oyamada and the southern part of the Iga areas.

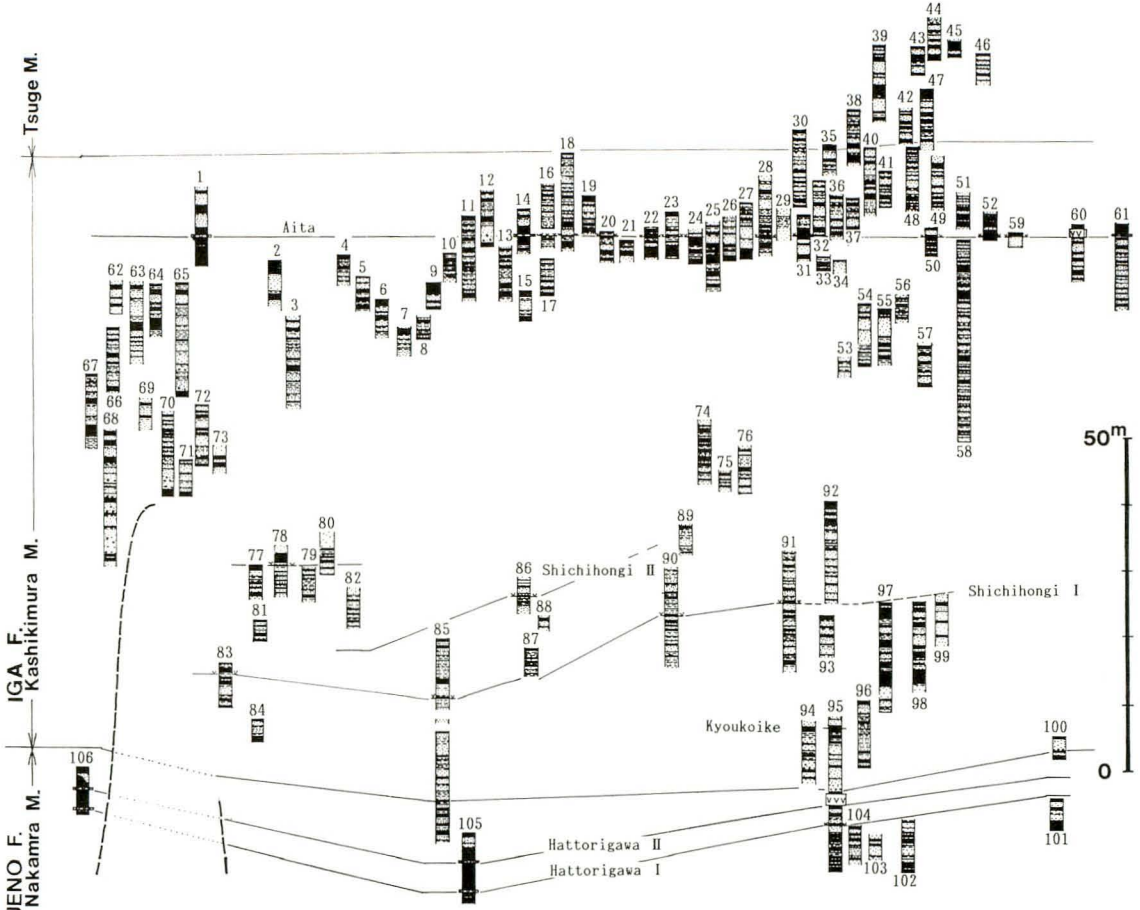

Tsuge M.
IGA F.
Kashikimura M.
UENO F.
Nakamra M.
Aita
Shichihongi II
Shichihongi I
Kyoukoike
Hattorigawa II
Hattorigawa I
50m
0

Fig. 19(a)

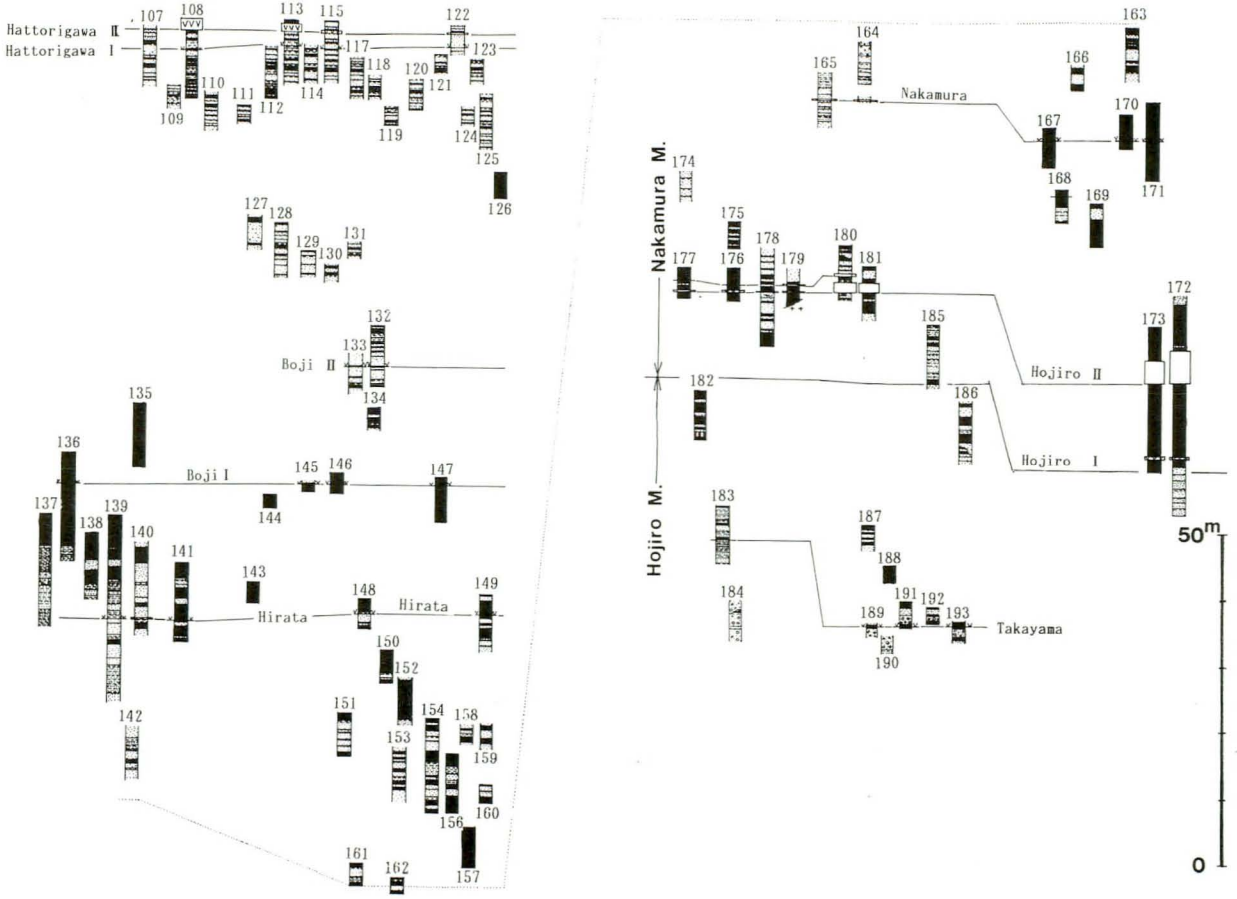


Fig. 19(b)

Fig. 19 Columnar sections of the Oyamada and the southern part of the Iga areas. Locality of each columnar section is shown in Fig. 15.

5. Iga and Oyamada areas

In the Iga and the Oyamada areas, the Ueno Formation, of more than 350 m in thickness, is lithologically divided into two members. These are the Hojiro and the Nakamura Members in ascending order.

a. Hojiro Member

The Hojiro Member unconformably overlies the basement Ryoke Granitic Rocks and Ryoke Gneissose Rocks, and is overlain by the Nakamura Member. This member, ranging from 50 to 70 m in thickness, consists of gravels and sand beds of granitic and gneissose origin with seams of silt and clay.

The Hojiro Member crops out around Hojiro and south to east of Nakamura. The type locality is situated along the road from Takayama to the north of Hojiro in Ueno City.

The gravels, which are dominant in the lower part of this member, range from 0.5 to 2 m in thickness. Pebbles of muddy gneissose rocks are dominant and the matrix is sandy. The base of each gravel bed is erosional and/or horizontal. The sand beds range from 20 to 70 cm in thickness and have trough- to horizontal-type cross stratification. The base of each bed is commonly horizontal or irregularly erosional. The seams of silt and clay range from 20 to 50 cm in thickness. They are poorly sorted and contain granitic or gneissose sand grains. Vegetational biotervation and fossil roots of plants are common in these fine beds.

b. Nakamura Member

The Nakamura Member measures 150 m in thickness and consists chiefly of thick clay beds with some sand beds. This member underlies the Iga Formation conformably in this area. The Nakamura Member is distributed in the southern part of the Oyamada area. The type locality is situated along the road to the east of Boji in Oyamada Village.

The clay beds range from 20 to 30 m in thickness. Each clay bed is chiefly massive with occasional weakly laminated parts, and commonly includes fossil shells. Each sand bed ranges from 4 to 6 m in thickness. The deposits is composed of medium to fine sand beds (20 to 80 cm in thickness) and has a wide extention of more than 200 m horizontally. Trough- or planar-type cross laminae or current ripples are found within it. The base of each sand bed is almostly parallel. The seams of silt, ranging from 10 to 40 cm in thickness, are intercalated in the sand beds. In each silt bed, horizontal or current ripples are commonly observed.

Around Hojiro in the southern part of the Iga-Oyamada area, the lower part of the Najamura Member changes to a sand-rich facies which consists of sand beds of granitic and gneissose origin with intercalating silt or clay beds.

Within the Nakamura Member, more than eight volcanic ash layers are intercalated. They comprise the Hojiro I, Hojiro II, Nakamura, Hirata, Boji I, Boji II, Hattorigawa I and Hattorigawa II Volcanic Ash Layers.

6. Ayama area

In this area, the Ueno Formation measures 40 m in thickness and is overlain con-

formably by the Iga Formation. The Ueno Formation consists of poorly-sorted clay and arkose sand beds, which contain granules of chert. In the Ayama area, it crops out around Yakio and Makiyama, Ayama Town in the western part of the area. This sequence is newly assigned to the lower part of the Aurahi Member of the Iga Formation (KAWABE, 1981).

Within the uppermost part of this formation, more than two volcanic ash layers are intercalated. They comprise the Yakio I and Yakio II Volcanic Ash Layers in ascending order, and correspond to the Kaminosho I and Kaminosho II Volcanic Ash Layers in the Hananoki area.

7. Koka area

In the Koka area, the Ueno Formation, of 70 m in thickness, is exposed at the east margin of the area, along the Tongu Fault. The Ueno Formation consists chiefly of poorly-sorted clay beds, arkose sand beds with seams of lignite beds and gravel beds. Around Aburahi, Koka Town, in the southeast of the Koka area, the lower part of the formation is composed chiefly of gravels. Their clasts are composed of fragments of chert, sandstone, hornfels, granite and aplite with small amount of Koto Rhyolitic Rocks.

B. Iga Formation

The Iga Formation is characterized by gravels containing large amounts of pebbles to cobbles of Koto Rhyolitic Rocks. This formation is widely exposed in the Shimagahara area, the northern part of Hananoki area, the Ayama area and the southeastern part of the Koka area. The Iga Formation is generally conformable with the Ueno Formation below, although in parts of Shimagahara area and the western part of the Hananoki area, it lies unconformably on the Ueno Formation.

The Iga Formation, of 150 m in maximum thickness, is composed mainly of gravels, sand and silt beds. The clast size in this formation increases westwards laterally to the west margin of the Shimagahara area and decreases upwards. The Iga Formation is divided into two members in the Iga and Oyamada areas which are designated as the Kashikimura and the Tsuge Members, and into two members in the Ayama and Koka areas which are designated as the Aburahi and the Tsuge Members in ascending order.

1. Hananoki area

In this area, the Iga Formation is more than 160 m in maximum thickness, and consists mainly of gravels which contain large amounts of pebbles of Koto Rhyolitic Rocks and sand beds with seams of silt and clay. The Iga Formation in the Hananoki area overlies the Ueno Formation unconformably in the western part of the area and conformably in the eastern part. This formation reveals a fining-upward sequence. The Iga Formation in the Hananoki area is divided lithologically into two members. These are designated as the Ishiuchi and the Hokke Members in ascending order.

a. Ishiuchi Member

This member, of about 70 m in total thickness, consists mostly of gravels with seams of silt and sand. The Ishiuchi Member is widely distributed in the northern part of

the Hananoki area. The type locality is situated along the road from Ishiuchi, Tsukigase Village, to Shirakashi, Ueno City. The clast size in this formation increases northwestwards to Ishiuchi.

The gravels, ranging from 3 to 4 m in thickness, are composed of pebbles to cobbles of Koto Rhyolitic Rocks, chert, shale, aplite and granitic rocks. The base of each gravel is irregularly erosive. Large-scale trough-type cross-laminae (1 to 3 m in width and 20 to 50 cm in depth) are found in the gravels. The seams of sand, ranging from 10 to 50 cm in thickness, overlie the gravels. The base of each seam of sand is irregular or parallel. When the seam has trough- or planar-type cross laminae, the base is mostly irregular and when the seam has parallel laminae, the base is parallel.

The clast size of the Ishiuchi Member increases westwards to Ishiuchi, and the seams of sand and silt thicken eastwards.

Within the Ishiuchi Member, more than three volcanic ash layers are intercalated. They comprise the Kyokoike, Shichihongi I and Shichihongi II Volcanic Ash Layers in ascending order.

b. Hokke Member

The Hokke Member, of more than 90 m in thickness, consists of sand and silt to clay beds with intercalating lenticular gravels. This member shows a gradually fining upwards. The Hokke Member is distributed in an area of the northern part of the Hananoki area, along the Hananoki fault from Shirakashi to Ikejiri in Ueno City. The type locality is situated along the road from east of Shirakashi to northeast of Shirakashi.

The silt to clay beds range from 0.1 to 2 m in thickness and have root remains of plants and vegetational biotervation. The sand beds range from 0.1 to 1 m in thickness. When the bed is thin, the sand is fine- to medium-grained in size and displays parallel to current-ripple laminae. When the bed is thick, the sand is coarse- to medium-grained in size and has trough- to planar-type laminae. The lenticular gravels range from 2 to 4 m in thickness. The base of each bed is asymmetrically concave. The beds have chiefly inner structures of epsilon-type cross-stratification. These gravels are composed of pebbles of Koto Rhyolitic Rocks, chert, sandstone and shale of the Tamba Belt, and granite and aplite of the Ryoke Complex.

Within the Hokke Member, more than eight volcanic ash layers are intercalated. They comprise the Shirakashi I, Shirakashi II, Jisonji, Hokke I, Hokke II, Hokke III and Hokke IV Volcanic Ash Layers in ascending order.

2. Shimagahara areas

In the Shimagahara area, the Iga Formation is more than 80 m in thickness. It overlies the basement granitic rocks and the Ueno Formation unconformably. The Iga formation is widely distributed in the Shimagahara area, and it reveals a fining-upward sequence. The lower part of the Iga Formation consists mainly of gravels with intercalations of sheets of sand and silt. The upper part of the formation is made up chiefly of sand and silt to clay beds with intercalations of lenticular gravels. This formation is divided into two members which are designated as the Kitamata and the Okuda Members

in ascending order.

a. Kitamata Member

The Kitamata Member, of 30 to 40 m in thickness, consists mainly of gravels with intercalations of sand and silt. This member crops out widely in the Shimagahara area. The type locality is situated along the road from Kitamata to Okuyamada, Minamiyamashiro Village, Nara Prefecture. The Kitamata Member overlies the Ueno Formation unconformably. The erosion attains more than 20 m.

The gravels range from 1 to 3 m in thickness, and consist of pebbles to cobbles of Koto Rhyolitic Rocks, chert, sandstone, hornfels, granite and aplite. Their matrix is composed of arkosic coarse grained sand. The base of each gravel is irregularly erosional. The sheets of sand, ranging from 20 to 40 cm in thickness, overlie the gravels. The seams of silt, of 10 to 50 cm in thickness, overlie the sheets of sand. They are usually completely eroded by overlying gravels.

Aruond Nakamura, the Kawamoto Mine and east of Tayama, where granitic rocks of the basement crop out as islands, the Kitamata Member consists chiefly of silt and clay beds with sand beds. Within these fine sediments of the Kitamata Member at Nakamura, more than two volcanic ash layers are intercalated. They comprise the Shimagahara I and Shimagahara II Volcanic Ash Layers in ascending order.

b. Okuda Member

The Okuda Member, of more than 40 m in thickness, consists of gravels, sand, silt and clay beds. This member is distributed in the northern part of the Shimagahara area, along the Kizugawa Fault from Osahihara, Minamiyamashiro Village, to Higashitakakura, Ueno City. The type locality of the Okuda Member is situated along the road from Hirode to Nishidegawa, Ueno City.

The gravel beds, ranging from 0.2 to 1 m in thickness, consist of pebbles. Each gravel bed grades upwards into the overlying sand beds. The sand beds, of 0.5 to 2 m in thickness, show grading in their grain size from coarse-grained with small pebbles to medium-grained. Within the lower part of each sand bed, low-angle trough-type cross-laminae are found. The silt and clay beds, of 20 to 70 cm in thickness, overlie the sand beds.

In a westward and an upward direction, the grain size of the Okuda Member fines, and the sand and gravel beds thin. Around Higashitakakura in the eastern part of the area, this member is composed of alternations of fine- to medium-grained sand, silt and clay beds.

3. Southeastern hills of Ueno City

In this area, the Iga Formation crops out at the top of the northwestern edge of the hills, at Shijuku-cho, Ueno City. The formation is more than 10 m in thickness and consists of sandy gravel beds which are composed of pebbles to granules. The clasts consist of fragments of chert, Koto Rhyolitic Rocks and hornfels. The Iga Formation overlies the Ueno Formation conformably.

4. Iga-Oyamada area

The Iga Formation, of 140 m in total thickness in this area, overlies the Ueno Formation conformably. The Iga formation reveals a fining-upward sequence. Its lower part is composed mainly of coarse sand beds with granule- to small pebble-grained gravel, and its upper part consists of alternations of sand, silt and clay. Based on these two parts, the Iga Formation in the Iga and Oyamada areas is divided into the Kashikimura and the Tsuge Members in ascending order.

a. Kashikimura Member

The Kashikimura Member, of 90 m in thickness, consists chiefly of gravely sand beds and well sorted sand beds with sheets of silt and clay. This member crops out from the northwestern part of Oyamada Village to the southeastern part of Iga Town. The type locality is situated along the road from Kashikimura, Oyamada Village to Aita, Iga Town.

The gravely sand beds range from 0.3 to 2 m in thickness. They generally have an irregularly erosional base. Large-scale cross stratifications occur in these beds and within these cross stratifications, sheets of silt are occasionally intercalated. The well sorted sand beds attain a thickness of from 0.2 to 1.5 m and are widely traceable. Small-scale trough-type, parallel or current-ripple laminae are found in these sand beds. The beds have a slightly irregular base and grade upwards into sheets of silt and clay. The sheets of silt and clay range from 10 to 80 cm in thickness and are also widely traceable. Parallel- or current-ripple laminae occur weakly in these sheets.

Within the Kashikimura Member, more than four volcanic ash layers are intercalated. They comprise the Kyokoike, Shichihongi I, Shichihongi II and Aita Volcanic Ash Layers in ascending order.

b. Tsuge Member

The Tsuge Member, of 70 to 80 m in thickness, consists of well sorted sand, silt and clay beds. It overlies the Kashikimura Member conformably, and is conformably overlain by the Wata Member of the Ayama Formation. The Tsuge Member reveals a fining-upward sequence. This member is widely distributed in the northern part of Iga Town. The type locality is situated on the large cliff in front of JR Tsuge station.

The sand beds in the lower part of this member attain a thickness of from 2 to 3 m and consist of coarse-grained sand. In the upper part of the member, they range from 0.5 to 1 m in thickness and are composed of fine- to medium-grained sand. Each of the sand beds generally has no structure in its lower part and small-scale trough-type cross-laminations, parallel or current-ripple laminae in its upper part. The silt and clay beds range from 1 to 2 m in thickness, and grade gradually downwards into sand beds.

5. Ayama and Koka areas

The Iga Formation in the Ayama and the Koka areas, of about 40 m in thickness, overlies the Ueno Formation conformably. It consists of arkose sand and silt beds. The lower part of the Iga Formation is sandy, and the upper part is silty. Based on this lithology, the Iga Formation is divided into two members. These are designated as the Aburahi and the Tsuge Members in ascending order.

a. Aburahi Member

The Aburahi Member, of 20 to 90 m in thickness, is distributed in the central to western part of the Ayama area and the eastern part of the Koka area. The type locality is situated on the cliffs in front of JR Tsuge station to the River Yamanota. The Aburahi Member consists chiefly of silt, clay, arkose sand beds and gravels.

At the type locality, the Aburahi Member attains a thickness of 90 m and reveals a fining upward sequence. The lower part of this member is composed of gravels and arkose sand beds with seams of silt and clay. The gravels, ranging from 1 to 5 m in thickness, consist of sub-angular to sub-rounded pebbles to cobbles of chert, granite, granoporphyrite and hornfels. The upper part of the member consists of alternations of arkose sand, silt and clay. Each bed ranges from 1 to 3 m in thickness and is not so continuous laterally.

The clast size of this member increases eastwards to Nagano, Koka Town, laterally. The Aburahi Member varies markedly in its thickness, measuring 90 m in the southeastern part of the Koka area, and 20 m in the Ayama, southwestern part of the Koka, and northeastern part of the Koka areas.

The lower part of the Aburahi Member contains the Shichihongi I Volcanic Ash Layer. In its upper part, more than three volcanic ash layers are intercalated. They comprise the Wata, Nakatomoda and Kamitomoda Volcanic Ash Layers in ascending order.

b. Tsuge Member

In the Ayama and the Koka areas, the Tsuge Member measures 12 to 80 m in total thickness. It consists of alternations of sand, silt and clay. The sand beds range from 2 to 3 m in thickness and consist of coarse-grained sands in the lower part of this member. They range from 0.5 to 1 m in thickness and are composed of medium- to fine-grained sands in the upper part.

The Tsuge Member varies markedly in its thickness, measuring 80 m in the southeastern part of the Koka area, 20 m in the Ayama and southwestern part of the Koka areas, and 18 m in northeastern part of the Koka area.

C. Ayama Formation

The Ayama Formation overlies the Iga Formation conformably, and is conformably overlain by the Koka Formation. The Ayama Formation crops out in the Ayama, the Koka and northern part of the Iga and Oyamada areas. The type locality is situated along the road from Tamataki, Ayama Town, to Nogawa, Konan Town. The Ayama Formation measures 130 m in maximum thickness, and its thickness is extremely variable. The Ayama Formation is subdivided into two members. These are designated as the Wata and the Konan Members in ascending order.

1. Wata Member

The Wata Member consists mainly of massive clay with more than three sand beds. This member corresponds to the Ayama Member (KAWABE, 1981).

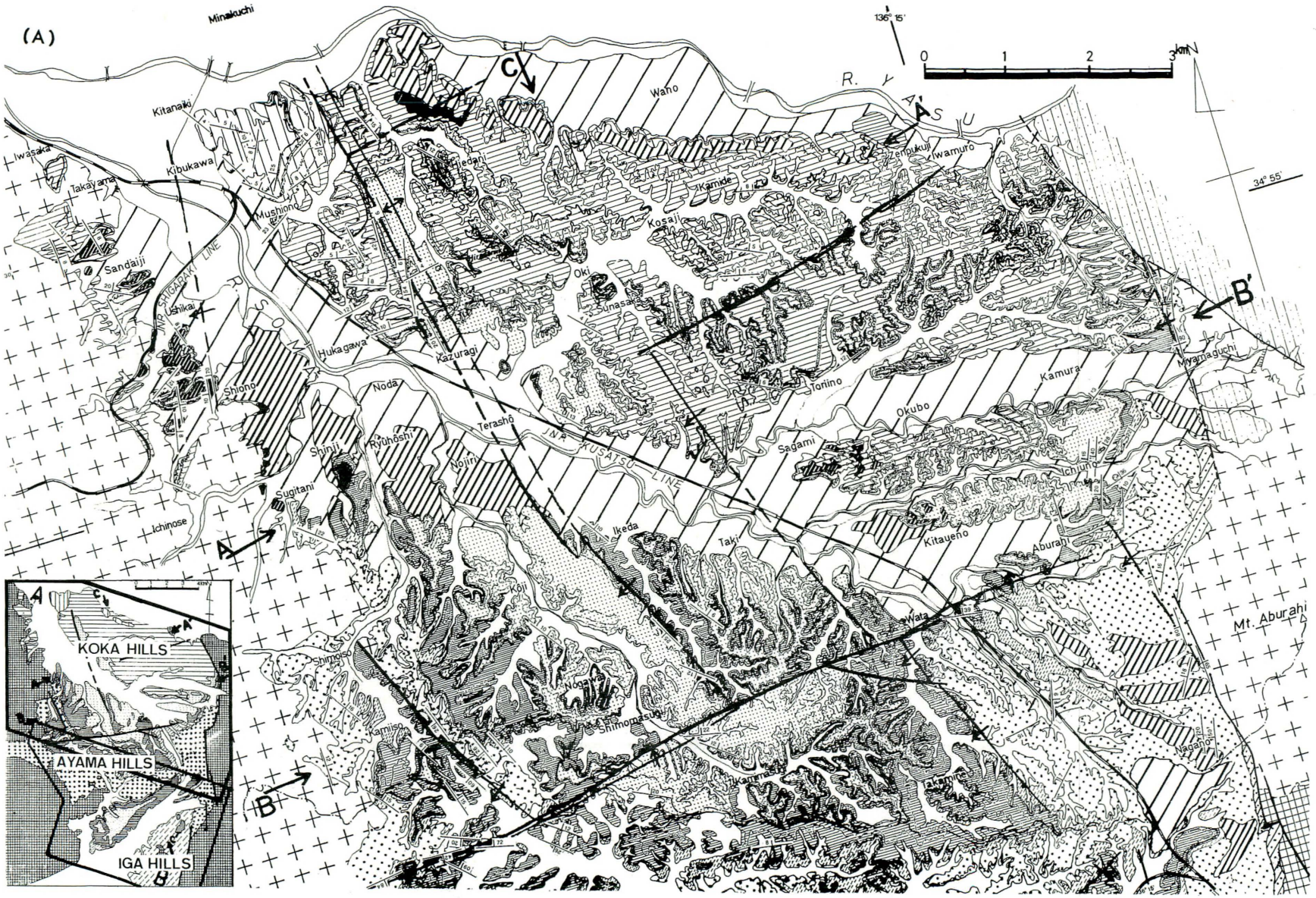


Fig. 20-a Geological map of the Ayama and Koka areas (a).

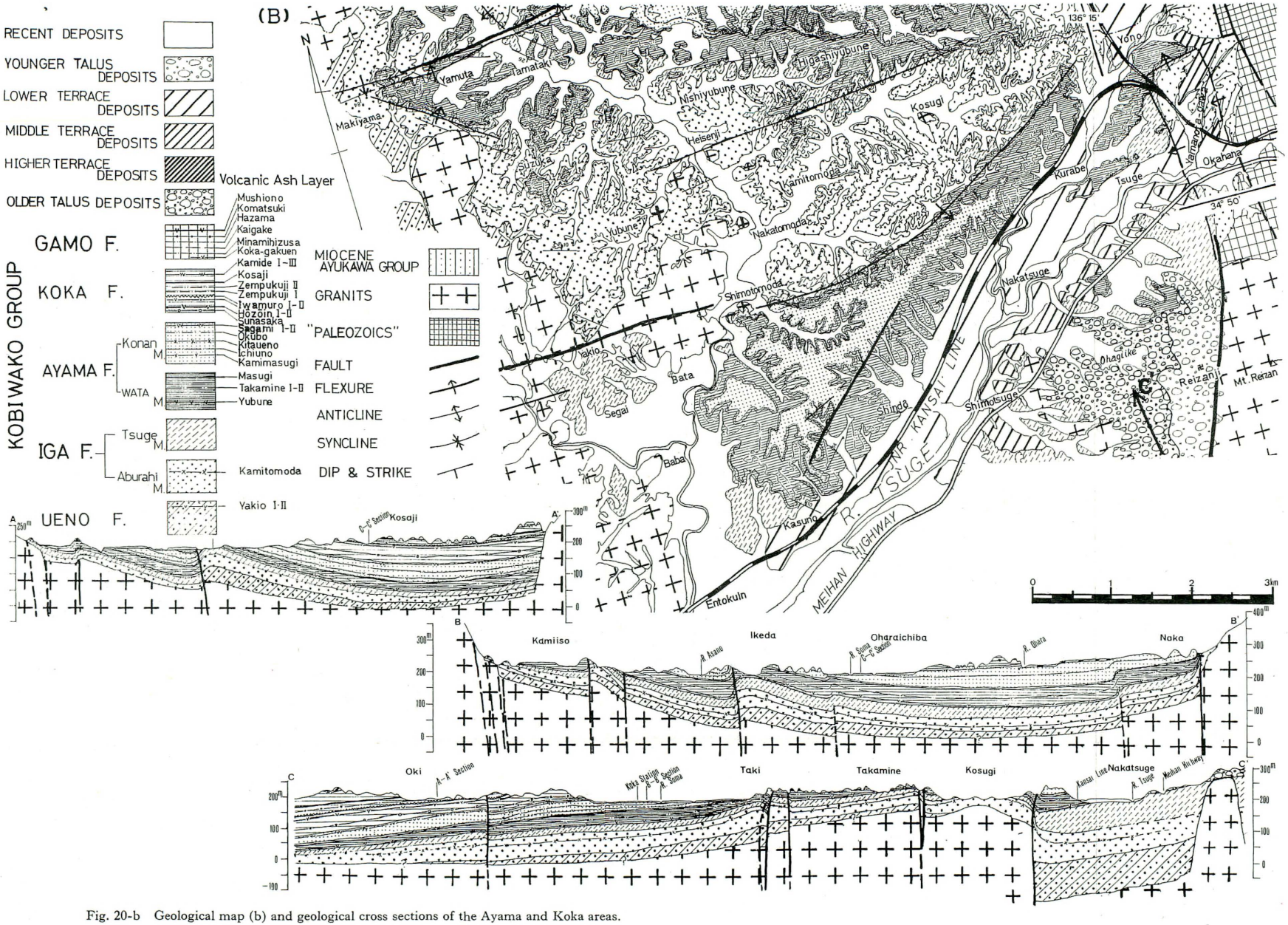
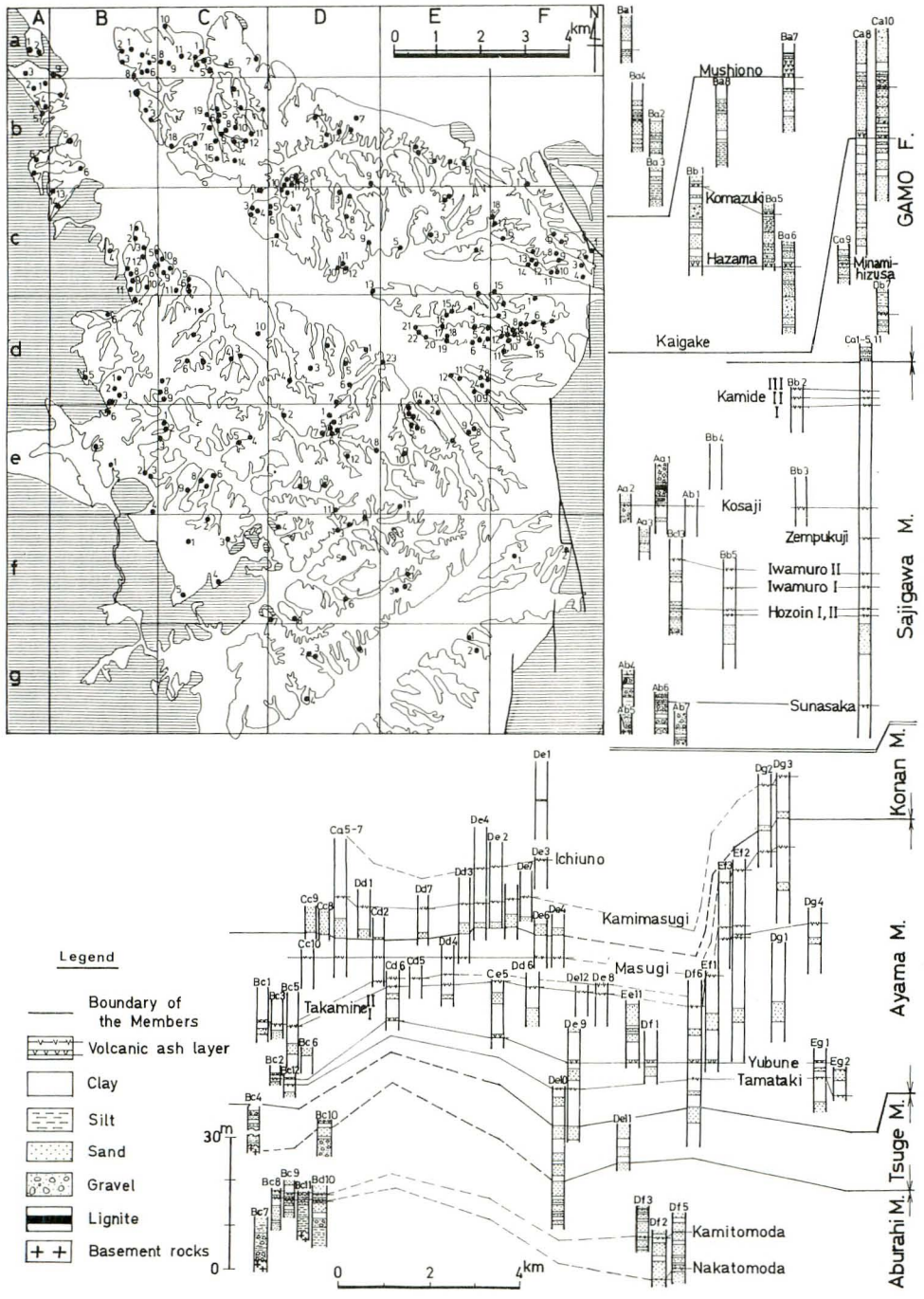


Fig. 20-b Geological map (b) and geological cross sections of the Ayama and Koka areas.


A
B
C
D
E
F
N
0 1 2 3 4 km
a
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c
d
e
f
g
Mushiono
Komazuki
Hazama
Kaigake
Minami-hizusa
GAMO F.
Kamide III II I
Kosaji
Zempukuji
Iwamuro II
Iwamuro I
Hozoin I, II
Sunasaka
Sajigawa M.
Konan M.
Ichiuno
Kamimasugi
Masugi
Takamine II
Yubune
Tamataki
Ayama M.
Tsuge M.
Aburahi M.
Kamitomoda
Nakatomoda
Legend
Boundary of the Members
Volcanic ash layer
Clay
Silt
Sand
Gravel
Lignite
Basement rocks
30m
0
0 2 4 km

Fig. 21(a)

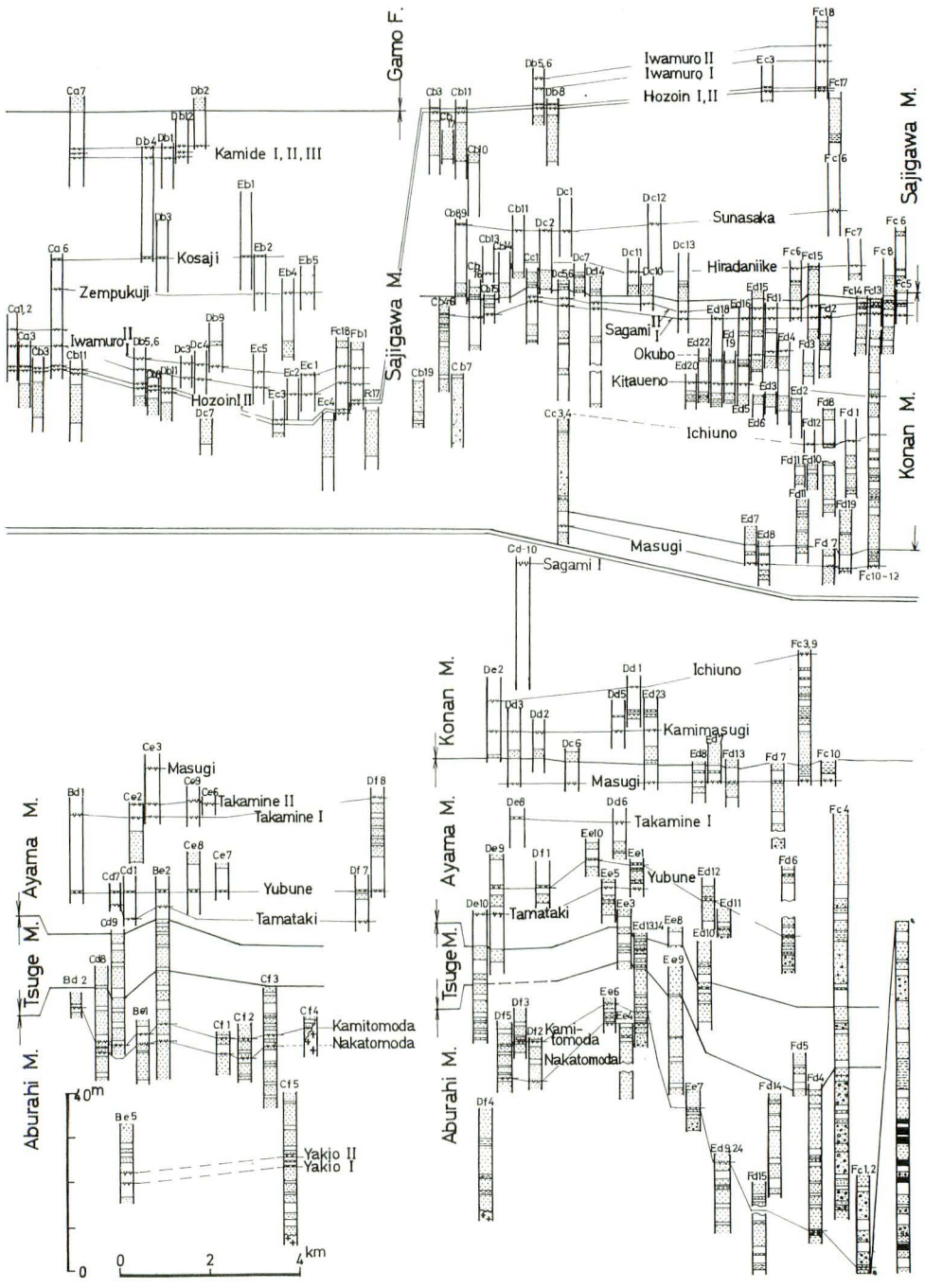

Fig. 21(b)

Fig. 21 Columnar sections and index map of each columnar section in the Ayama and Koka areas.

The Wata Member is extremely variable in its thickness, ranging from 28 to 72 m. It crops out in the northern part of the Iga and Oyamada areas, the southern and northern parts of the Ayama area, and the southeastern part of the Koka area. The type locality of the Wata Members is situated along the road from Tamataki, Ayama Town, to Kooji, Koga Town.

Around the type locality, this member is 28 m in thickness and consists of massive clay with a sand bed. This sand bed is 1.5 m in thickness and lies at a horizon in the lowest part of the member, between the Yubune and Takamine I Volcanic Ash Layers.

In the Iga and the Oyamada areas, the Wata Member is intercalated by two sand beds. One of these beds occurs at a horizon in the lower part of the member, between the Tamataki and Yubune Volcanic Ash Layers, while the other sand bed occurs at a horizon in the middle part of the member, between the Takamine II and Masugi Volcanic Ash Layers. Each of these sand beds becomes both thicker and coarser-grained to the northeast. Each sand bed has a tongue-shaped profile in the horizontal plane, measuring 6 to 8 km in length, and 1 to 3 km in width. The long axes of sand bodies are parallel to the faults and flexures which exist along them.

In the southeastern part of the Koka area, the Wata Member consists of alternations of thick clay and sand beds. The clay beds range from 3 to 6 m, while the sand beds are 1 to 2 m in thickness.

Within the Wata Member, more than five volcanic ash layers are intercalated. They comprise the Tamataki, Yubune, Takamine I, Takamine II and Masugi Volcanic Ash Layers in ascending order.

2. Konan Member

The Konan Member, which overlies the Wata Member and overlain by the Sajigawa Member, is 40 to 60 m in thickness. The Konan Member consists mostly of massive and thick clay beds with some sand beds in the Ayama area. In the Konan area, it is composed of alternations of silt, sand, and gravel beds (KAWABE, 1981).

The Konan Member crops out in the northern part of the Ayama area and the southeastern to central part of the Koka area. The type locality is situated along the road from Kaminogawa to Kamimasugi, Konan Town.

Around the type locality, this member consists of a sand bed (2 m in thickness) which occurs at a horizon in the base of the member, and a clay bed which is 38 m in thickness. The Konan Member in the Koka area reaches 60 m in maximum thickness. It is made up chiefly of coarse-grained sand and/or gravels in the western part of the Koka area and alternations of thick sand (1 to 5 m) and thick clay (4 to 7 m in thickness) in the eastern part. Each of the sand beds becomes both thicker and coarser-grained to the northwest and northeast. The grain size grades north-northwestwards in the western part and the northeastward in the eastern part. In the northwestern part of the Koka area, the Konan Member consists mainly of gravels which are composed of small pebbles of chert, granite and Koto Rhyolitic Rocks with an arkosic coarse grained sandy matrix.

Within the Konan Member, more than seven volcanic ash layers are intercalated.

They comprise the Kamimasugi, Ichiuno, Kitaueno, Okubo I, Okubo II, Sagami I and Sagami II Volcanic Ash Layers in ascending order (KAWABE, 1981).

D. Koka Formation

The Koka Formation, of 130 m in maximum thickness, consists chiefly of thick clay beds with more than three sand beds. It overlies the Ayama Formation conformably and is overlain by the Gamo Formatin conformably. The Koka formation occurs in the central to northern part of the Koka area. The type locality is situated on cliffs along the River Sajigawa. This formation consists of one member which is designated as the Sajigawa Member.

1. Sajigawa Member

The Sajigawa member, of 75 to 120 m in thickness, is composed of thick massive clay beds with more than three sand beds (KAWABE, 1981). The lower most part of this member, of 6.5 m in thickness, comprises a medium- to coarse-grained sand bed. Above this, the lower part, of 25 m in thickness, consists of a massive clay bed. Within this part the Hiradaniike and Sunasaka Volcanic Ash Layers are intercalated in ascending order. The lower middle part of the member, of 12 m in thickness, is made up of coarse-grained sand beds with granules. The upper middle part, of 15 m in thickness, consists of a massive clay bed. Within this part, the Hozoin I, Hozoin II, Iwamuro I and Iwamuro II Volcanic Ash Layers are intercalated in ascending order. The upper part of the member, of, 5.5 m in thickness, is composed of sand beds. This sandy part is restricted in distribution to the northeastern part of the Koka area. The uppermost part, of 55 m in thickness, comprises of a massive clay bed. In this part, the Zempukuji, Kosaji, Kamide I, Kamide II and Kamide III Volcanic Ash Layers are intercalated in ascending order.

Each of the sandy parts has a coarsening upward sequence and becomes both thicker and coarser-grained to the east-southeast to east. It reveals a tongue-shaped profile in the horizontal plane, which is 4 to 10 km in length, and 1 to 5 km in width. The long axes of such profiles extends west-northwestwards to west.

E. Gamo Formation

The Gamo formation constitutes the uppermost formation in the survey area. It overlies the Koka Formation conformably, and is distributed in the northwestern part of the Koka area and the hilltop of Koka Hill. This formation, of 150 m in thickness, consists of alternations of sand, silt and clay in survey area. It is subdivided lithologically into three members. These are designated as the Nunobikiyama, the Hazama and the Kiyota Members in ascending order.

1. Nunobikiyama Member

The Nunobikiyama Member, which overlies the Koka Formation conformably and is overlain conformably by the Hazama Member, is composed chiefly of sand beds with clay and silt beds. This member is 70 m in thickness, and occurs in the northwestern

part of the Koka area and the hilltop of the northern part of Koka Hill. The type locality is situated along the road to the east of a farm, northeast of Kibukawa, Minakuchi Town. The Nunobikiyama Member reveals an upward coarsening in its lower part, of 15 m in thickness, and a fining-upward sequence in its upper part, of 55 m in thickness.

The lower part of this member consists of well-sorted sand, silt and clay beds. The beds are 0.5 to 1 m in thickness. They extend widely, for more than several hundred meters in width, with little change in thickness and lithofacies. The upper part of this member is composed of poorly-sorted sand, silt and clay beds. The sand beds range from 0.2 to 3 m in thickness, and have lenticularly erosional or horizontal bases. The silt and clay beds range from 0.5 to 2 m in thickness, are frequently vegetationally biotervated.

Within this member, more than four volcanic ash layers are intercalated (KAWABE, 1981). They comprise the Naiki, Minamihizusa, unnamed, and Kaigake Volcanic Ash Layers in ascending order.

2. Hazama Member

The Hazama Member (KOBIWAKO RESEARCH GROUP, 1977), which overlies the Nunobikiyama Member conformably and is overlain conformably by the Kiyota Member, consists chiefly of clay beds with sand beds. In the survey area, this member occurs in the northwestern part of the Koka Hill, around Naiki and Mushono, Minakuchi Town. It is made up of poorly-sorted silt and clay beds with lenticular sand beds (KAWABE, 1981).

Within the Hazama Member, more than two volcanic ash layers are intercalated. They comprise the Hazama and Komazuki Volcanic Ash Layers in ascending order (KAWABE, 1981).

3. Kiyota Member

The Kiyota Member (KOBIWAKO RESEARCH GROUP, 1977) comprises the uppermost beds in the survey area. This member, of 50 m in thickness, consists of well-sorted sand, silt and clay beds. It occurs in the hilltop of the northwestern part of the Koka Hill, and overlies the Hazama Member. It reveals a fining-upward sequence.

Within the Kiyota Member in this area, more than three volcanic ash layers are intercalated. The middle one is the Mushono Volcanic Ash Layer and the others are unnamed.

IV Geologic structures around the Ueno basin

The Kobiwako Group lies in fault contact with the basement rocks along the eastern boundary of the group, and is in unconformable contact (abutting) along its western and southern boundaries. The fault along the eastern boundary of the group is clearly apparent as a topographic feature involving steep and linear scarps between the Ueno basin and the Suzuka Mountains.

The Kobiwako sedimentary basin around the Ueno basin is characterized by a prevalence of faults and flexures which trend in north-northwest, east-northeast and

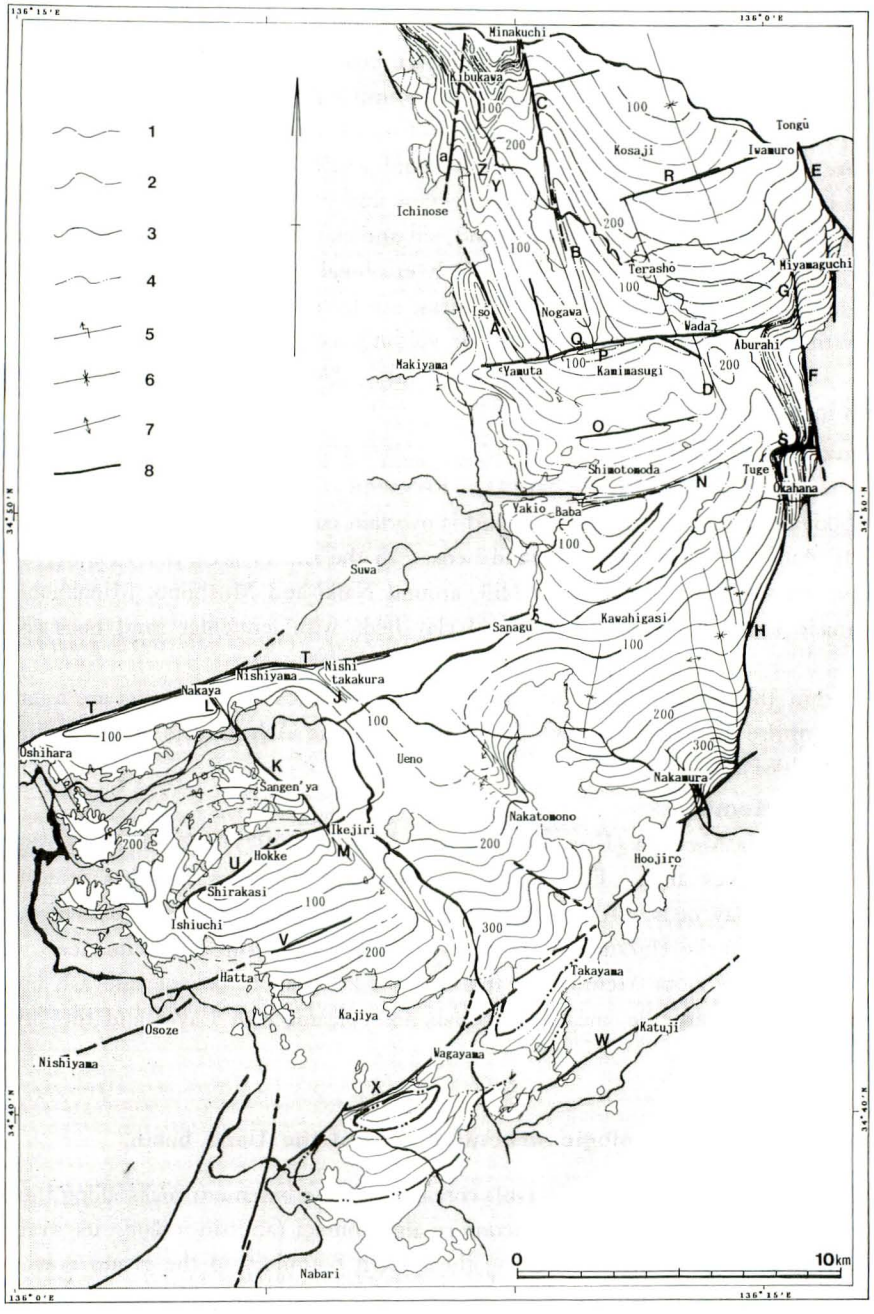

Fig. 22 Geologic structures around the Ueno Basin, shown by structure contour lines of the volcanic ash layers (1: Sagami, 2: Masugi, 3: Kaminosho I, 4: Ichibe Volcanic Ash Lyers). A~X show major faults and flexures (see Table 1).

Table 1 Characteristics of each geologic structures around the Ueno Basin.

Alphabet on map	Name	Locality	Length (km)	Direction of axis or fault plain	Vertical displacement (net slip) (m)	T*1	Df*2	Deformation of the Kobiwako Group	
								Width of deformation	maximum dip
A	Isoo Flexure	Tamataki～Shimoisoo	3	NNW-SSE	40～80	F	WSW	200	R70°E
B	Katuragi Flexure	Shimomasugi～west to Minakuchibashi	10	NNW-SSE	20～80	F	WSW	100～200	45°W～80°W
C	Katuragi Fault	Ikeda～west to Minakuchibashi	6	N15°E80°E	10～15 50～60	R	WSW		
D	Wata Flexure	Gotanda～Wata	3	NNW-SSE	30～70	F	WSW	100	60°W
E	Tongu Fault	east to Ichiuno～Tongu	10	N10°W70°E	250+	R	WSW	200	R80°E
F	Aburahi Fault	Okahana～Aburahi	6	N10°W60°E	300+	R	WSW	150	R50°E
G	Aburahi Flexure	Aburahi～west to Kamura	3	NNW-SSE	60～150+	F	WSW	100	36°W～70°W
H	Tsuge Fault	southwest of Tsuge～east to Hirata	6	N15°E65°E		R	WSW	200	R65°E
I	Tsuge Flexure(I)	southeast to Tsuge～northwest to Tsuge	2.5	NNW-SSE	100～160	F	WSW	250	90°
J	Higashi-takakura Flexure	north to Takakura～east to Takakura	1.5	NW-SE	60	F	E	100	60°E
K	Sangenya Fault	north of Ikejiri～south to Nakaya	3.5	NNW-SSE	50	R	WSW	-	-
L	Nakaya Flexure	south to Nakaya～Nakaya	2	NNW-SSE	40	F	WSW	100	35°W
M	Ikejiri Flexure	east of Ikejiri～northeast to Ouchi	1.5+	NNW-SSE	20+	F	WSW	30	50°W
N	Iga-Ayama Flexure	Segai～Kurabe	6	ENE-WSW	20～80	F	SES	150	70°S～R70°N
O	Tomoda Faults	Yubune～Takamine	6	ENE-WSW	$\frac{20}{2\sim5/e}$*3	R	SES		20°S～40°S
P	Makiyama-Aburahi Flexure	Makiyama～Aburahi	10	ENE-WSW	50～80	F	NWN	100～150	40°S～75°S
Q	Makiyama-Aburahi F.	Makiyama～Aburahi	9	N82°E80°N	50～80	R	SES	100～150	40°S～75°S
R	Kosaji Faults	east to Oki～Iwamuro	4	ENE-WSW	$\frac{1\sim15}{0.5\sim5/e}$*3	N	SES		
S	Tsuge Flexure(II)	north to Tsuge～north to Okahana	1.5	ENE-WSW		F	NWN	200	80°N
T	Kizugawa Fault	Kizu～Entokuin	30	N70°W54°N	500～600	R	SES	150～200	85°N
U	Hananoki Fault	north to Ishiuchi～Ikejiri	6	N46°E52°E	50～200	R	SES	50	78°N
V	Hatta-toho Fault	east to Hatta～Yamade	2.5	N68°E78°S	12	N	SES		
W	Katsuji Fault	Ao～Shimomano	10	ENE-WSW	100+	R	SES		
X	Nishitahara Fault	Nishitahara～northwest to Maruyama	7	ENE-WSW	200+	R	SES	60	R80°N
Y	Shinji Anticline	Shinji～Koshinku	6	NNW-SSE		A	ENE		5°E～6°E*4 10°W～30°W*5
Z	Mushono Syncline	Sugitani～Mushono	6	NNW-SSE		S	ENE		10°W～30°W*4 5°E～12°E*5
a	Shiono Flexure	Shiono～west to Sanbonmatu	4	NNW-SSE	80	F	ENE	200	R85°E

T*1: type of geologic structure (F: flexure, R: reverse fault, N: normal fault, A: anticline, S: syncline),
Df*2: Direction of footwall, *3: net slip per each fault, *4: east-notheast wing, *5: west-southwest wing

north-northwest directions. These faults and flexures of different trends cut one another, and form rectangular and paralleologrammatic fault-blocks. The faults and flexures cut the older geologic structures of the Ryoke Complex which trend generally in a west-northwest direction. Within each block, the Kobiwako Group generally dips north-northwest at an angle of 3 to 6°.

Two systems of faults are distinguished around the Ueno basin. One is that deform-

ing the Kobiwako Group, and the other is that which is covered by the Kobiwako Group. The faults and flexures deforming the Kobiwako Group are considered to have moved respectively during deposition of the group.

1. Faults covered by the Kobiwako Group

This system of faults and flexures is parallel to that deforming the Kobiwako Group, and is also parallel to the unconformity along the western margin of the group. The faults trending east-northeast dip both north and south, and the faults trending north-northwest dip both east and west. This system of faults is without a consistent tendency in direction of dip.

2. Geologic structures deforming the Kobiwako Group

a. Faults and flexures

This system of faults and flexures is outlined in detail in Table 1. The respective structures are consider to have existed and moved during deposition of the Kobiwako Group, since each component member varies in thickness between the faults and flexures. These structures tend to be oriented in the same direction as the faults covered by the group. Each fault and flexure trending east-northeast dips north, and those trending north-northwest dip west. Most of these faults are high-angle reverse faults.

b. Folding

The folds are also shown in detail in Table 1. The comprise broad synclines (4 to 8° in both wings) which trend north-northwest, and whose axes plunge gently (4 to 6°) north-northwest.

V Sedimentary age of the lower part of the Kobiwako Group

Paleomagnetic and fission-track dating studies on water-laid volcanic ash layers in the Kobiwako Group have been carried out by several researchers (NISHIMURA and SASAJIMA, 1970; YOKOYAMA *et al.*, 1977; KOBIWAKO RESEARCH GROUP, 1977, 1981; HAYASHIDA and YOKOYAMA, 1983; ITIHARA *et al.*, 1984). The results of these studies revealed that the Kobiwako Group ranges from the Gauss normal epoch to the early half of the Brunhes epoch in its geomagnetic age, and from about 400 Ma to about 300 Ma in its absolute age.

Recent progress in the author's stratigraphic survey of the lower part of the Kobiwako Group from the Ueno to the Ayama Formations, has included a paleomagnetic and fission-track dating study (KAWABE, DAISHI and KIMURA, MS). The results are summarized in Fig. 3, along with those of the above mentioned studies. Talking these data together, the sedimentary age of the lower part of the Kobiwako Group from the Ueno to the Koka Formations is estimated to be as follows. The Ueno Formation ranges from the latest stage of the Gilbert epoch to the early half of the Gauss epoch, just earlier than the Mammos event, and from about 3.8 Ma to 3.1 Ma. The Iga Formation ranges from the Mammos event to a stage between the Mammos and Kaena events in the Gauss epoch, and from about 3.1 Ma to just later than 3.0 Ma. The Ayama Formation ranges from

a stage between the Mammos and Kaena events in the Gauss epoch to the lower three-quarters of the Gauss epoch, and from just later than 3.0 Ma to about 2.7 Ma. The Koka Formation ranges from the lower three-quarters of Gauss epoch to the latest Gauss epoch, and from about 2.7 Ma to 2.5 Ma.

VI Lateral variation in thickness and facies of each formation or member

Each formation or member of the lower part of the Kobiwako Group varies laterally in thickness on each fault-block, and also varies laterally in litho-facies.

1. Lateral variation in thickness of each formation or member

The thickness of each member in each area is listed in Table 2. From the data given, the features of the lateral variation in thickness can be summarized as follows:

a. The thickness of each member is extremely variable between each fault-block.

b. The location of the maximum thickness of each member is situated on subsiding fault-blocks, and that of the minimum thickness is situated on uplifting blocks.

c. In each fault-block, the location of the maximum thickness of each member exists along the margin of the block.

d. In the Koka block, the members of the Ueno to Ayama Formations increase in thickness southward. On the other hand, the Koka Formation increases in thickness northward.

2. Lateral variation in litho facies of each formation or member

The lateral variation in litho facies of each formation or member can be summarized as follows:

Ueno Formation: The Ueno Formation decreases in grain size from the west, south and northeast of its distribution to the Iga and Oyamada areas.

Iga Formation: The Iga formation is characterized by gravels of Koto Rhyolitic Rocks. The grain size decreases eastwards, and intercalations of sand and silt beds also increase eastwards. This formation reveals a fining-upward sequence.

Wata Member: The Wata Member of the Ayama Formation is characterized by thick clay beds with intercalations of several sand beds, which reveal a coarsening-upward sequence. Each sand bed increases northeastwards in both its thickness and grain size, and has a tongue-shaped profile.

Konan Member: The Konan Member of the Ayama Formation is characterized by an extreme litho-facies change between the northwestern and southern parts of its distribution. In the southern part, this member is composed mostly of thick and massive clay beds. On the other hand, in the northwestern part, it consists chiefly of sand and gravel beds.

Koka Formation: The Koka Formation is characterized by thick clay beds with intercalations of several sand beds, which reveal a coarsening-upward sequence. Each sand

bed increases east-southeastwards and/or to the east in both its thickness and grain size, and has an tongue-shaped profile.

VII Sedimentary environments of each formation

Based on the features of the lateral variation in litho facies and the characteristics of the beds comprising the various formations, their sedimentary environments can be evaluated as follows.

Ueno Formation: A shallow lake existed around the Oyamada area. Brooks flowed into this lake from the west, south and northeast. Around these brooks, back-marshes or swamps existed in the Hananoki area, the southeastern hills of Ueno City, the Ayama area and the northeastern part of the Koka area.

Iga Formation: A large braided river flowing eastwards was widely distributed around the Ueno basin, even around the Oyamada area in the early stage of the Iga Formation. In the late stage of this formation, a shallow lake was again present around the Oyamada area, and meandering rivers with associated, back-marshes and swamps were distributed in the Hananoki, Shimagahara, Ayama and Koka areas.

Wata Member: A large stable lake existed in the Iga, Oyamada, Ayama and the northwestern part of the Koka areas. Deltas were sometimes developed around the Koka, Ayama and Iga areas from the northeast, from the Suzuka Mountains.

Konan Member: A stable lake existed in the Ayama area. On the other hand, fan-deltas from the north and/or northwest were developed in the Konan area and the northwestern part of the Koka area.

Koka Formation: A large lake existed in the Ayama and Koka areas. Deltas were sometimes developed from the east-northeast and/or east, from the Suzuka Mountains.

Gamo Formation: Braided rivers and/or deltas existed widely in the Koka area.

VIII Sedimentary basin of the lower part of the Kobiwako Group

1. Unconformity along the margin of the Kobiwako sedimentary basin

Beyond the eastern margin of the sedimentary basin, where it is in fault contact, the Kobiwako Group generally abuts against the basement rocks. The unconformity varies in its angle of dip and the linearity of its plane on the depositional stages from the Ueno to Ayama Formations. The angle of dip varies from a high angle (30 to 50°) to a low angle (20 to 30°), and the linearity varies from straight to irregularly curved. These variations are evident on the depositional stages from the base of the Koka Formation to the top of this formation. The earliest straight unconformity plane trends in the same direction as the faults and flexures in the sedimentary basin.

2. Sedimentary facies along the margin of the sedimentary basin

The sedimentary facies along the margin of the group also varies in its sorting and

Fig. 23 Geologic facies map around Isoo, Konan Town.
1 : volcanic ash layers, 2 : sorted clay of the Wata Member, 3 : Arkosic sand and silt of the Ueno and the Iga Formations, 4 : "Gaérome" clay, 5 : poorly sorted angular gravels.

Table 2 Thickness of each member of the lower part of the Kobiwako Group in each area around the Ueno Basin.

Formation or Member	Thickness in each area (meters)											
	Shimaga-hara	Hana-noki	SE of Ueno	Iga and Oyamada	Ayama		Koka			Konan		Isoo
					NW	SE	NW	SE	NE	NW	SE	
Koka F.	-	-	-	-	-	-	80	100	120	-	-	-
Konan M.	-	-	-	-	-	-	40	60	-	50	45	-
Wata M.	-	-	-	72	30	50	30	50	-	30	50	43
Iga F.	80+	160	-	170	30	80	70	160	-	0+	0+	70+
Ueno F.	40	150	130	230	30	40	30	70	-	-	-	-

grain size on the depositional stages from the Ueno to Ayama Formations and from the base of the Koka Formation to the top of this formation. The lowest Ueno Formation and the lowest part of the Koka Formation consist chiefly of debris- and/or talus-like poorly sorted angular gravels which contain huge-scale clasts of more than 2 m in maximum diameter (Fig. 23). These clasts are composed only of fragments of the basement rocks from just behind the basin. The Iga Formation and the middle part of the Koka Formation are made up chiefly of fanlike sorted subangular to subrounded pebbly gravels. These gravels are composed of fragments of the basement rocks from just behind the basin, together with those carried from the farther hinterland mountains. The Ayama Formation and the upper part of the Koka Formation consist of fan-deltaic and/or lacustrine fine sediments. The grain sizes are finer than those of the underlying formations.

3. Topographic changes at the margin of the sedimentary basin

The above features permit the following general reconstruction of the sequence of topographic changes. Steep and straight scarps existed along the margin of the sedimentary basin during the embryo period of deposition of the Ueno Formation and during the lowest part of the Koka Formation. They were 200 to 400 m in height. Subsequently dissection of the scarps began to occur, so that valleys were eventually formed and fan-deltas appeared along the scarp-foot. Finally, the scarps became eroded and a stable topography was developed.

4. Origin of the sedimentary basin

In the basement rocks along the margin of the sedimentary basin, faults covered by the Kobiwako Group are found. They trend in the same directions as the faults and flexures in the sedimentary basins; namely, north-northwest, east-northeast and north-northwest. These directions are also the same as those of the trend of the unconformity. The faults and flexures in the sedimentary basin began to occur in the basement rocks during the embryo period of the sedimentary basin, as evidenced by the fact that the Kobiwako Group varies in thickness an facies on both sides of each flexure and fault (Table 2). As a result, it can be inferred that the scarps were formed by the fault move-

ments. In fact, it hardly seems possible that diastrophism took place without any faulting along the margin of the sedimentary basin. This suggests that the basin arose through the fault movements and rapid subsidance of the fault-blocks. At first, fault movements occurred, and the basement rocks were cut into many fault-blocks. More than nine blocks, located around the Ueno and the southeastern part of the Omi basins, then subsided rapidly. These area of subsidence become the sedimentary basin for the Ueno, Iga and Ayama Formations.

5. Migration of the sedimentary basin

At the stage of the Koka Formation, the area in which the maximum thickness of this formation developed is situated to the north of that of the Ueno, the Iga and the Ayama Formations. The former is located in the north of the Koka area, and the later is located in its southeastern part. Moreover, coarse sediments were transported from east-southeast to west-northwest and/or from east to west at the stage of the Koka Formation, whereas they were transported from north to south and/or northeast to southwest at the stage of the Ueno, the Iga and the Ayama Formations. These facts indicate that the sedimentary basin migrated from south to north just before the stage of the Koka Formation.

Similar facies changes and topographic changes at the unconformity, such as those of the Ueno to Ayama Formations, are also found along the margin of the Koka Formation. This suggests that fractural block movement of the basement rocks resulted in the migration.

Before the migration, at the stage of the Konan Member, coarse sediments which were carried from the northern hinterland increased in volume and in grain size. It may be inferred from this that the northern hinterland had uplifted, and the faulting which led to the new sedimentary basin then occurred before the migration of the sedimentary basin.

IX History of the sedimentary basin

The history of the sedimentary basin of the lower part of the Kobiwako Group will now be descrived as a conclusion to this study (Fig. 24). Changes to the sedimentary basin occured as revealed by the paleocurrents, gravel composition and sedimentary facies. These features will be discussed in detail in a separate paper.

The sedimentary environments of each formation can be summarized as follows:
[Early stage of the Ueno Formation] The sedimentary basin of the lower part of the Kobiwako Group developed around the Ueno basin. It was 10 km wide in an east-west direction and 25 km long in a north-south direction. Fault scraps were formed on the margin of this sedimentary basin. They were 200 to 400 m in height. Mass movement deposits such as debris flows, mud flows, talus and landslide deposits piled up on the marginal part of the basin. Marsh sediments covered the gentle surface relief of the basement rocks in its central part. Some sandy sediments were transported into

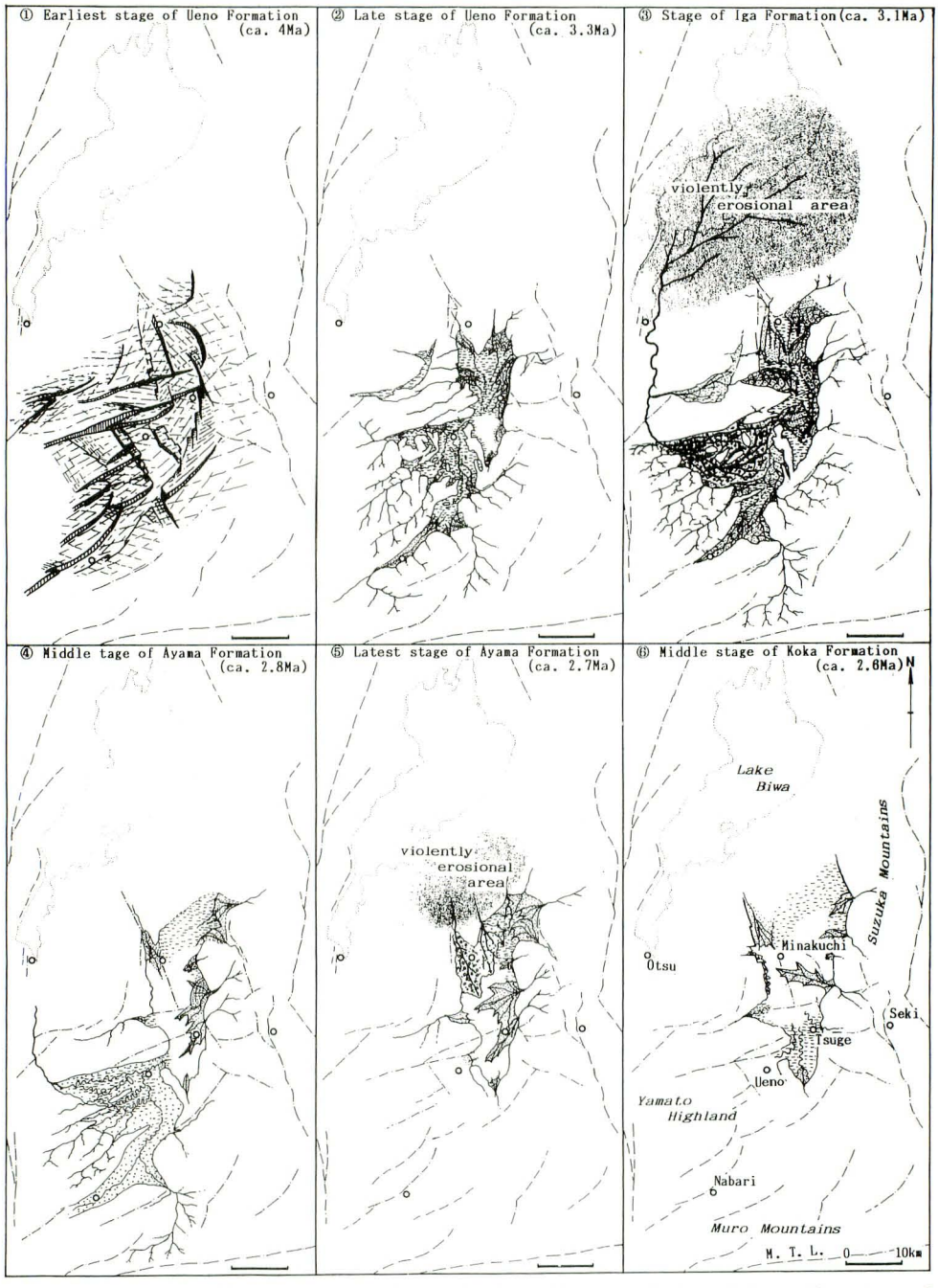

Fig. 24 Paleogeographic maps around the Kobiwako sedimentary basins of the earliest stage of the Ueno Formation to the middle stage of the Koka Formation.

the marshes by brooks. Then, by dissection of the hinterland mountains, alluvial fan-deltas of about 1 to 3 km, in radious were formed at the foot of the mountains. In the basin itself, a shallow lake appeared in the Oyamada area.

[Late stage of the Ueno Formation] The sedimentary basin slowly subsided and its sedimentary area expanded to the southern part of the Omi basin and the Shimagahara area. The sedimentary area which consisted of hills or low mountains with broad hollows at the early stage of the Ueno Formation underwent a change in its environment to a sedimentary area with marshes.

[Early stage of the Iga Formation] A huge volume of gravel was transported down by a large river. The length of the river is inferred to have been about 50 km, and it flowed eastwards to the sedimentary basin. The head of the river was situated in the eastern area of present-day Lake Biwa. Due to the huge volume of gravel supplied, the Shimagahara area become changed in its environment from a swampy to a fluvial one which was characterized by braided rivers.

[Late stage of the Iga Formation] The large river waned. A shallow lake again appeared in the Iga and Oyamada areas, and a flood plain with a meandering river occupied the Hananoki area.

[Early stage of the Ayama Formation] The above mentioned river waned, and the lake become expanded to the Ayama and Koka areas. This stage represented one of the most stable stages of the Kobiwako sedimentary basin.

[Late stage of the Ayama Formation] The lake still existed around the Iga, Oyamada and the southern part of the Ayama and Koka areas. However, the lake waned in the northern part of the Ayama and Koka areas, because sand and gravels were transported from the uplifted north-northwestern hinterland mountains to those areas by rivers.

[Stage of the Koka Formation] The lake migrated to the north. This stage was also one of the most stable stages of the Kobiwako sedimentary basin.

[Stage of the Gamo Formation] The lake again migrated to the north. The sedimentary basin expanded widely in the southern half of the Omi basin. It is inferred that the depositional area of the Ueno, Iga and Ayama Formations changed to the uplifting area at this stage.

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